ELECTRICAL PROPERTIES OF BUBBLES AS THEY AFFECT THE FLOTATION OF CASSITERITE

FINAL REPORT

by

COMINCO LIMITED

TECHNICAL RESEARCH CENTRE

TRAIL, B.C.

Work on the project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada.

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ABSTRACT

The object of this study was to examine the possibility of recovering fine cassiterite particles not recovered by conventional flotation, by means of a novel electrostatic flotation mechanism. This was to be accomplished by finding conditions where opposite bubble and particle charges would aid recovery by simple electrostatic attraction.

The charge on the bubble as a function of chemical conditions in the solution was evaluated by measuring the streaming current generated by a rising stream of nitrogen bubbles. The charge on the particle under comparable conditions was determined by measuring the zeta potential using conventional streaming potential methods.

Only limited confirmation of a simple electrostatic flotation mechanism was found as the tin collectors evaluated in this study failed to exhibit a region where the bubble and particle had opposite charges.

RÉSUMÉ

Le but de cette étude était d'examiner la possibilité de recouvrer de fines particules de cassitérite, non récupérées par les méthodes conventionnelles de flottation, en utilisant un nouveau méchanisme de flottation électrostatique. Ceci devait être accompli en trouvant les conditions où la charge sur la bulle et sur la particule sont opposées ce qui, par simple attraction electrostatique, aiderait la récupération.

La charge sur la bulle en fonction des conditions chimiques de la solution était évaluée par la mesure du potentiel d'écoulement généré par un courant ascendant de bulles d'azote. La charge sur la particule, sous conditions chimiques similaires, était déterminée par la mesure du potentiel zéta en utilisant des méthodes conventionnelles de potentiel d'écoulement.

Seule une confirmation restreinte d'un simple méchanisme de flottation électrostatique a été trouvé, car les collecteurs d'étain évalués dans cette étude n'ont pas produit de régions où la bulle et la particule avaient une charge opposée.

INTRODUCTION

Very fine cassiterite present in Canada's base metal mines at Kimberley, Kidd Creek and Bathurst is presently unrecovered due to limitations in existing gravity and flotation processes. The present study was undertaken to determine the applicability of a novel electrostatic flotation mechanism discovered by scientists at CANMET for the treatment of fine oxide minerals. The process requires determining pulp chemistry conditions in which charges are present on fine mineral species and simultaneously an opposite charge is present on the collection bubbles. The application of the process to selective flotation of minerals relies on further determining conditions in which the specific collective charge is present only on the mineral of economic interest.

This process has been demonstrated by CANMET scientists for the recovery of fine quartz minerals. The present study is an extension of that earlier work to a problem in selective flotation of oxide minerals with very similar surface characteristics and strong covalent bonding.

OUTLINE OF THE INVESTIGATION

The investigation consisted of measuring the streaming current, zeta potential and flotation response of appropriatley sized fractions of quartz and cassiterite at various pH's in different collector systems. The study was divided into three sections:

a) Measurement of Streaming Current

The streaming current generated by a rising stream of nitrogen bubbles in an aqueous solution of various cassiterite collectors was measured using apparatus and techniques based on the previous CANMET study [1]. The variables were pH, collector type and collector concentration.

b) Measurement of Zeta Potential

The zeta potential of pure cassiterite and pure quartz were measured using a streaming potential method [2]. This was carried out for each mineral at the same sets of collector systems, concentrations and pH's as those employed in part 1.

Quartz was included in the study as it is the major gangue mineral which interferes with selectivity during cassiterite flotation.

c) Flotation Response Versus Particle Size

In the final part of the study, micro-flotation tests were performed for three sized fractions of quartz and cassiterite at the "best" collector concentrations determined in parts 1 and 2. These tests were conducted at the same pH levels as the previous work.

d) Collectors Used in the Study

Based on a review of the literature the following collectors and concentrations were chosen:

TABLE 1 Collector Type and Concentrations used in the Study

	Type[4]	Concentration (g/Mt)	Concentration (g/Mt)	Concentration (g/Mt)	Concentration[1] (mg/l)	Concentration[1] (mg/l)	Concentration[1] (mg/l)
Sodium Oleate	A	10	20	40	7	13	27
Sodium Lauryl Sulphate	A	6	12	24	4	8	16
Briquest 281-25S	A	200	300	400	133	200	267
Salicylaldehyde[2]	A	200	300	400	133	200	267
Aerosol 22[3]	A	25	50	100	17	33	67
Dodecylamine Hydrochloride	C	2	13	27	1	9	18
Styrene Phosphonic Acid	A	100	200	300	67	133	200
Procol 540[3]	A	75	113	150	50	75	100
Dowfroth 250 (frother)			20			13	

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1. Assumes the flotation feed is 40% solids with a slurry s.g.=1.3.

2. The salicyaldehyde was first dissolved in acetone as it is insoluble in water.

3. No frother was added to the Procol 540 or Aerosol 22 as it caused excessive foaming.

4. Type A is anionic, and C is cationic.

Briquest 281-25S => (2-Ethylhexyl)iminobis-(methylene phosphonic acid)

Aerosol 22 => Tetrasodium N - (1,2 dicarboxyethyl) - N - octadecyl sulfosuccinate

Procol 540 => Sulfosuccinate salt.

A list of reagent suppliers is given in Appendix E.

SUMMARY OF THE TESTWORK RESULTS

The summary of the results is divided into three sections which represent the three different phases of the project.

a) Measurement of Streaming Current

The graphs for streaming current versus pH are located in Appendix A, Figures A1-A8. Although there is scatter in the raw data the smoothed curves for each concentration have similar shapes. In fact the curves for all the collectors show a similar shape with low values for the streaming current at neutral pH and high negative values at both ends of the pH test ranges.

The curves for Dodecylamine Hydrochloride the only collector with a positive streaming current compare well with the literature [1]. Values for the other collectors typically ranged from -10 to -40 x 10^{-8} amps.

b) Measurement of Zeta Potential

The graphs for zeta potential of quartz and cassiterite versus pH are given in Appendix B, Figures B1-B16. Despite some scatter in the raw data the smoothed curves have the same general appearance for each collector concentration and even collector to collector. The basic shape has low values of zeta potential at the ends of the pH test range and high negative values at neutral pH.

Quartz

Of the 24 collector/concentration combinations tested 23 had a negative zeta potential typically ranging from -20 to -150 mv. Only dodecylamine hydrochloride at 0.018 g/L (8.1 X 10^{-5} M) had a positive zeta potential with a Zero Point of Charge (zpc) at pH 8.5. In this case the zeta potential was negative at lower pH's and positive at higher pH's. The curves for dodecylamine hydrochloride compare well with the literature [1].

In water quartz has a zpc at 2-3.7 with the zeta potential positive at lower pH's and negative at higher pH's [11].

Cassiterite

Of the 24 collector/concentration combinations tested 18 had a negative zeta potential typically ranging from -20 to -100 mv.

Both dodecylamine hydrochloride and salicylaldehyde had positive zeta potential's with a Zero Point of Charge at a pH of 3.5 to 4.0. In these cases the zeta potential was positive at lower pH's and negative at higher pH's.

In water cassiterite has a zpc at 4.5 with the zeta potential positive at lower pH's and negative at higher pH's [11]. Both dodecylamine hydrochloride and salicylaldehyde show this shape with the curve shifted lower on the pH scale.

c) Flotation Response Versus Collector

The original objective of this study was to estimate the effectiveness of an electrostatic flotation mechanism on fine cassiterite. However, after completion of the streaming current and zeta potential tests only 5 points were found where this mechanism would apply (on dodecylamine hydrochloride - a weak cassiterite collector and the only cationic collector in the test matrix). These results indicate that:

a) A cationic tin collector is required, however at present the only known cassiterite collectors are anionic. Cominco has actively been involved with the search for better cassiterite collectors. To date over 1300 reagents have been screened, 400 showed some ability to float cassiterite and of these 13 were selective. Further tests narrowed it down to 3 effective cassiterite collectors none of which was ever used commercially at Sullivan [12,13,14]. Work in this area continues on an itermittent basis.

b) A suitable modifying agent is required to reverse the charge on the surface of the cassiterite. It is known that the presence of ferric, bivalent nickel, cobalt, lead, and magnesium ions will change the charge on quartz surfaces from high negative to positive values [15]. While the presence of barium and aluminium cations can reverse the charge on cassiterite [21]. Further work, beyond the scope of the present study, could discover a suitable surface charge modifying agent for cassiterite and thus effect an electrostatic flotation mechanism.

Based on the test results the most selective cassiterite collectors tested were styrene phosphonic acid and Procol 540, (previous work done at Cominco had arrived at the same conclusion [12]). The collector which showed the least selectivity for cassiterite over quartz was salicylaldehyde.

The following table can be constructed from the test results where vg = very good, f=fair, p=poor:

TABLE 2 COLLECTOR RESPONSE AND SELECTIVITY VERSUS pH

	Cassiterite		Quartz		Most Selective
	Float	pH	Float	pH	pH
Sodium Oleate	VG	> 7	P	-	> 7
Sodium Lauryl Sulphate	VG	< 9	P	-	< 9
Briquest 281-25S	VG	< 8	F	< 6	-
Salicylaldehyde	P	6-8	F	< 7	-
Aerosol 22	VG	-	G	< 9	> 9
Dodecylamine Hydrochloride	G	> 7	VG	> 6	-
Styrene Phosphonic Acid	G	< 7	P	> 8	< 8
Procol 540	VG	< 9	VP	-	< 9

d) Flotation Response Versus Particle Size

Generally only the coarse -45 +38 um fractions showed any significant flotation results with the -10 um flotation results universally poor.

Figures 20-21 show flotation recovery versus a value[1] which is proportional to the difference in charge between the bubble and the particle. The minimal data indicate that an electrostatic mechanism may have some effect on the flotation of -45 +38 um quartz and possibly on the -45 +38 um cassiterite. The available data do not give any indication that the mechanism is operative for particles smaller than 10 um.

The graphs for the flotation recovery of each collector versus pH are shown in Figures 4-11 for quartz and 12-19 for cassiterite. The graphs also include streaming current and zeta potential (note that by convention, ZP is shown on the positive side of the axis).

Figures 23-24 show no significant correlation between streaming current and flotation recovery of coarse quartz or cassiterite.

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1. This value is the difference between the streaming current x 10^{-8} amps and the zeta potential in mv. While this is nonsensical in terms of units, these values are proportional to the absolute value of the charge on the bubble and the particle respectively. Therefore if all the tests are done with the same equipment this difference would be a qualitative measure of the electrostatic driving force.

Figure 25 shows no significant relationship between the recovery of quartz and its zeta potential. Figure 26 suggests a possible correlation between ZP and the flotation recovery of cassiterite at zeta potentials less than -150mv. However insufficient data are available to verify this.

While the zeta potential of the -65 +200M fraction was measured in the streaming potential cell, other work has found that the PZC and thus the zeta potential is affected by particle size [19]. Therfore in future investigations a check should be made that the zeta potential of these very fine -10 and -5 um particles is adequately represented by the coarse fraction. Electrophoretic techniques would be required for zeta potential measurement of these fine particles.

Quartz Flotation

The flotation response of the -45 + 38 um fractions was in the 20-40% recovery range except for dodecylamine hydrochloride which was 50-90%. The only collector which showed some flotation response for the -10 um fractions was dodecylamine hydrochloride at 10-30%.

Cassiterite Flotation

The flotation response of the -45 +38 um fractions was as expected with the known cassiterite collectors showing good recoveries of 60-90%. The flotation results for the -10 um fractions was uniformly poor with most recoveries less than 5%. This was anticipated by the lack of oppositely charged bubbles and particles and therfore no chance of an electrostatic flotation mechanism.

CONCLUSIONS AND RECOMMENDATIONS

Only limited confirmation of a simple electrostatic flotation mechanism was found and it may have been more effective on quartz than cassiterite.

At present there are some reservations about the efficacy of using zeta potential and streaming current as indicators of flotation characteristics. The methods used in this study required specialized equipment, trained personnel, pure reagents, de-ionized water and considerable practice before readings were repeatable. The problems encountered indicate that refinements in the equipment and techniques are still required to improve the

reproduceability of the results and overcome problems with electrode polarization.

Zeta potential and streaming current behaviour reflect changes in the charge carried by the particle and the bubble. The magnitude and sign of these charges influences the absorption of collector ions and thus the particles' ability to float. However confirmation must be sought that the zeta potential of the fine -10 and -5 um particles is adequately represented by measurments on any +200M particles.

In conclusion, this testwork indicates no potential for fine cassiterite recovery with the most effective cassiterite collectors currently known. However if a selective cationic collector or suitable charge modifying agent can be identified it should be tested for its potential to recover the fine cassiterite now un-recoverable at Canadian base metal producers.

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DETAILED DESCRIPTION OF THE TESTWORK

a) Measurement of Streaming Current

The streaming current generated by a rising stream of nitrogen bubbles in an aqueous solution of various cassiterite collectors was measured using apparatus and techniques based on the previous CANMET work [1]. The apparatus shown in Figure 1 was constructed of glass with a removeable top section, (the same bottom section and frit were used for the streaming current and the microflotation testwork). The electrodes were made from platinum wire on which Ag/AgCl was plated as in [3]. To maintain the accuracy of the electrodes the cell was kept full of water, protected from sunlight, and the electrodes shorted when a reading was not being taken.

The measurements were made at room temperature and involved adjusting the pH of a liter of solution[1] containing the collector/frother with NaOH or HCl. The cell was then filled and the nitrogen flow adjusted to 100 ml/min. The electrodes were unshorted and the internal cell resistance measured using a 1 KC AC source (General Radio Company - Model 1650A - Impedance Bridge). The external resistance was set to 2% of the internal resistance with a decade box (General Radio - Model 602N - Decade Resistance Box) and the voltage drop across the external resistance measured (Hewlett Packard - Model 3456A - Digital Voltmeter). The cell was then drained the pH of the solution adjusted and the procedure repeated.

As the Aerosol 22 and Procol 540 were too foamy to measure, the runs were repeated with no added frother. However the Aerosol 22 was still too foamy and so the original concentrations were reduced. This enabled us to measure the streaming current of the Aerosol 22 at all but the two lowest pH values (3.0 & 4.5) at the highest of the three new concentrations.

As suggested by the literature, polarization and stability problems were experienced with the electrodes [2,7]. Inital measurements made with a platinum wire electrode gave unstable voltage readings which tended to drift. Based on the literature the surfaces of the platinum were plated with a Ag/AgCl layer which dramatically improved the stability of the readings. However polarization effects were still a problem with some collectors (especially DAC and Aerosol 22). Various methods were used to reduce this ranging from taking the average of several hundred readings over 30 seconds, to draining the cell between the resistance and voltage readings. A method was considered

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1. All water used for these tests was distilled once then passed through a ion exchange column to give the equivalent of triple distilled water.

successful when the readings were repeatable. Due to experimental variability, 204 readings were taken versus the 144 originally planned.

b) Measurement of Zeta Potential

The zeta potential of pure cassiterite and pure quartz were measured using a streaming potential method [2]. The apparatus shown in Figure 2 was constructed mostly of glass with plastic joints. The zeta cell was constructed from a teflon rod with removable end sections so it could be charged with a sized fraction of the mineral. The chamber in the rod in which the mineral was charged was 5.7 cm long and 1.1 cm in diameter. The electrodes were prepared from discs of high purity platinum 2.5 cm in diamater, 0.8 cm thick with 0.175 mm diamater holes drilled in them. In order to reduce polarization effects a layer of Ag was plated on the platinum and then chloridized to produce a Ag/AgCl surface [3].

Before a new test series was started the system was flushed with HCl and then a solution with a known resistance (KCl at 0.1N) was used to determine the cell constant.

Nitrogen was used to pressurize a reservoir containing ~5 liters of solution adusted to the desired pH. The solutions to be measured and the reservoir were maintained at 30°C by a constant temperature bath. The exit valves on the reservoir were opened so solution would flow through the zeta cell until the pH of the solution exiting the cell had stablized. The valves would then be closed and the voltage readings (Hewlett Packard - Model 3456A - Digital Voltmeter) versus pressure drop (mercury manometer) across the cell recorded as the pressure fell. The valves would then be opened to generate another series of readings as the pressure rose. The system would then be de-pressurized the pH adjusted and the procedure repeated.

The voltage/pressure drop data was then passed to a regression routine to determine the best-fit slope (dE/dP). Typical r^2 terms for the regression were 0.99 or better. If the r^2 term was less than 0.95 the run was repeated. Few of the lines determined by this procedure had an origin of zero and often lines for repeat runs would have different origins [8]. However, the slopes and thus the zeta potentials were very consistent. The best-fit slope was converted to zeta potential using the standard Smoluchowski relationship (see Appendix B).

There were some problems with electrode polarization and reproducability of the test data. This was especially true at some of the low potentials ie. $-10 < ZP < 10$ mv as noted in [8]. However for the purposes of this study the absolute value of the ZP at these low levels was not required to evaluate the flotation results.

Quartz

Quartz was included in the study as it is the major gangue mineral which interferes with selectivity during cassiterite flotation. In this study the zeta cell was filled with -65 +100M quartz.

Cassiterite

The coarsest fraction of cassiterite which could be isolated from the Kimberley concentrate was -150 +200M. When placed in the zeta cell, it presented too high a pressure drop to the system and no measurements could be taken. In consultation with Canmet a new cell 0.5 cm in length was fabricated and filled with the fine cassiterite. This modified cell produced the required linear dE/dP results.

c) Microflotation of Quartz and Cassiterite

The microflotation recovery of cassiterite and quartz were measured using the apparatus shown in Figure 3. The flotation used the same basic apparatus as in the streaming potential runs with the addition of a Hallimond head and a peristaltic pump to inject the sample.

In these tests the apparatus was filled with solution containing the collector and the nitrogen flow was set to 100 ml/min. The feed bottle was filled with solution, 4 grams of the mineral, and conditioned for 5 minutes. The pump flow rate was set so the feed was added over 6 minutes. The concentrate and tails were then filtered, dried, weighed, and the recoveries calculated. Fresh solution and mineral would be added and the procedure repeated. All tests were conducted at room temperature.

During the sample preparation not enough material in each size fraction was recovered to use fresh material for each flotation test. As the time to prepare more was prohibitive it was decided to regenerate the sample after each series of tests. This involved washing the sample with HCl and burning off any remaining collector. Flotation tests performed before and after the regeneration procedure confirmed that the collector was removed.

The filtration of the coarse size fractions ran smoothly but the filtration of the fine -10 um particles sometimes took several hours using a vacuum aspirator. As no pressure filter setup could be devised that would not cause high sample loss for the small samples, often less than 0.5 grams, a vacuum pump was used to improve the driving force. This reduced filtration times to less than 1/2 hour per sample.

During the early flotation tests consistent, repeatable results were obtained with the points for each collector lying on a smooth curve. However when some of these tasks were repeated at the end of the testwork the curve had moved and the new points were also consistent and repeatable (Figure 27). As some of the collectors had lower recoveries and some had higher recoveries no explanation was found for this behaviour.

d) Preparation of Quartz Fractions

The quartz used in this study was from a sample of silica sand which had been leached in aqua regia for 48 hours. The quartz was further ground in a ceramic ball mill to produce the required size fractions. Details of the SEM analysis, Coulter Counter size analysis, and semi-quantitative analysis can be found in APPENDIX C.

e) Preparation of Cassiterite Fractions

A sample of tin concentrate was obtained from Cominco's Sullivan mine in Kimberley B.C. A combination of screening, grinding in a rubber lined ball mill, and fine settling techniques were used to separate the sample into the required size fractions. The sample was passed through a Franz isodynamic separator to remove any trace metallics and leached in $FeCl_3$ solution to remove any remaining sulphides. This produced a concentrate which assayed 97% cassiterite. Details of the SEM analysis, Coulter Counter size analysis, and semi-quantitative analysis can be found in APPENDIX C.

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FIGURE 1 – STREAMING CURRENT APPARATUS

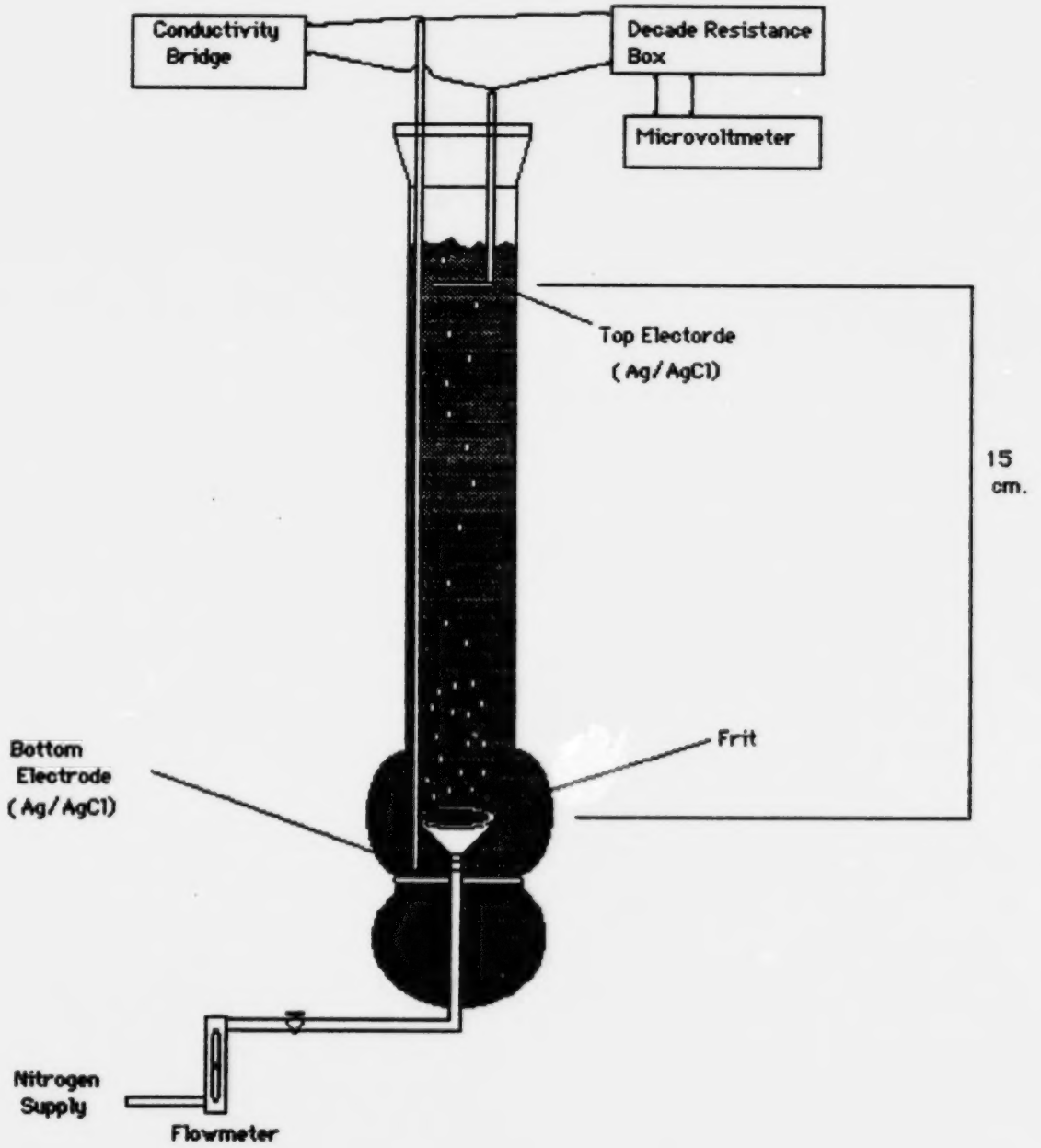


FIGURE 2A - STREAMING POTENTIAL APPARATUS

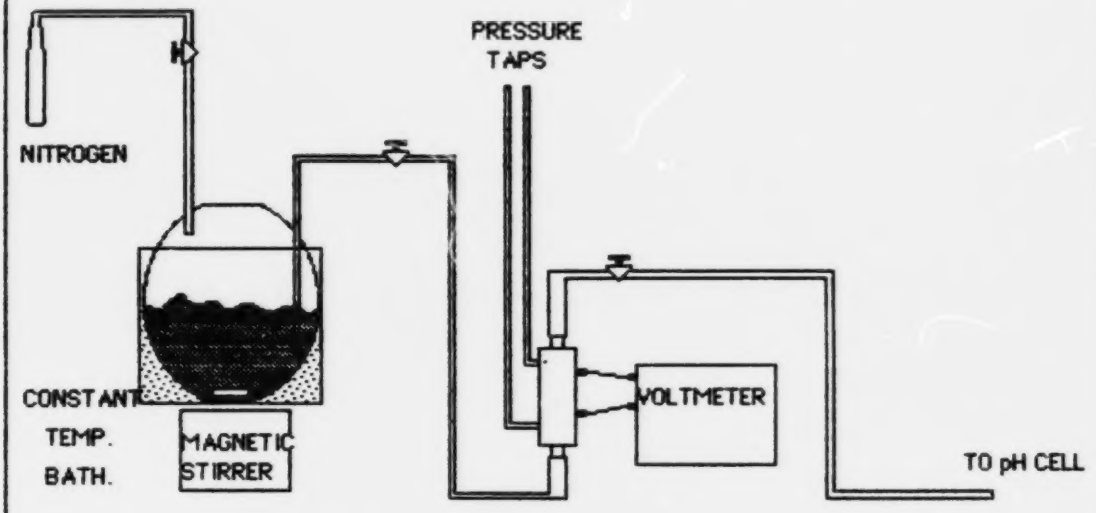


FIGURE 2B - SCHEMATIC OF STREAMING POTENTIAL CELL

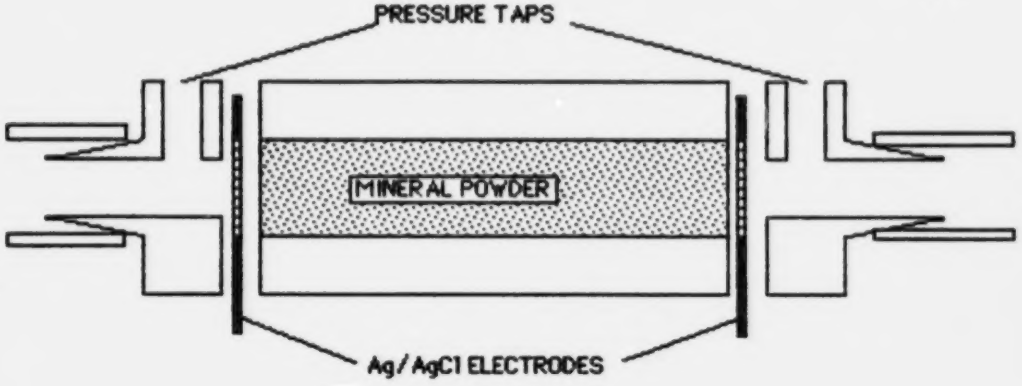
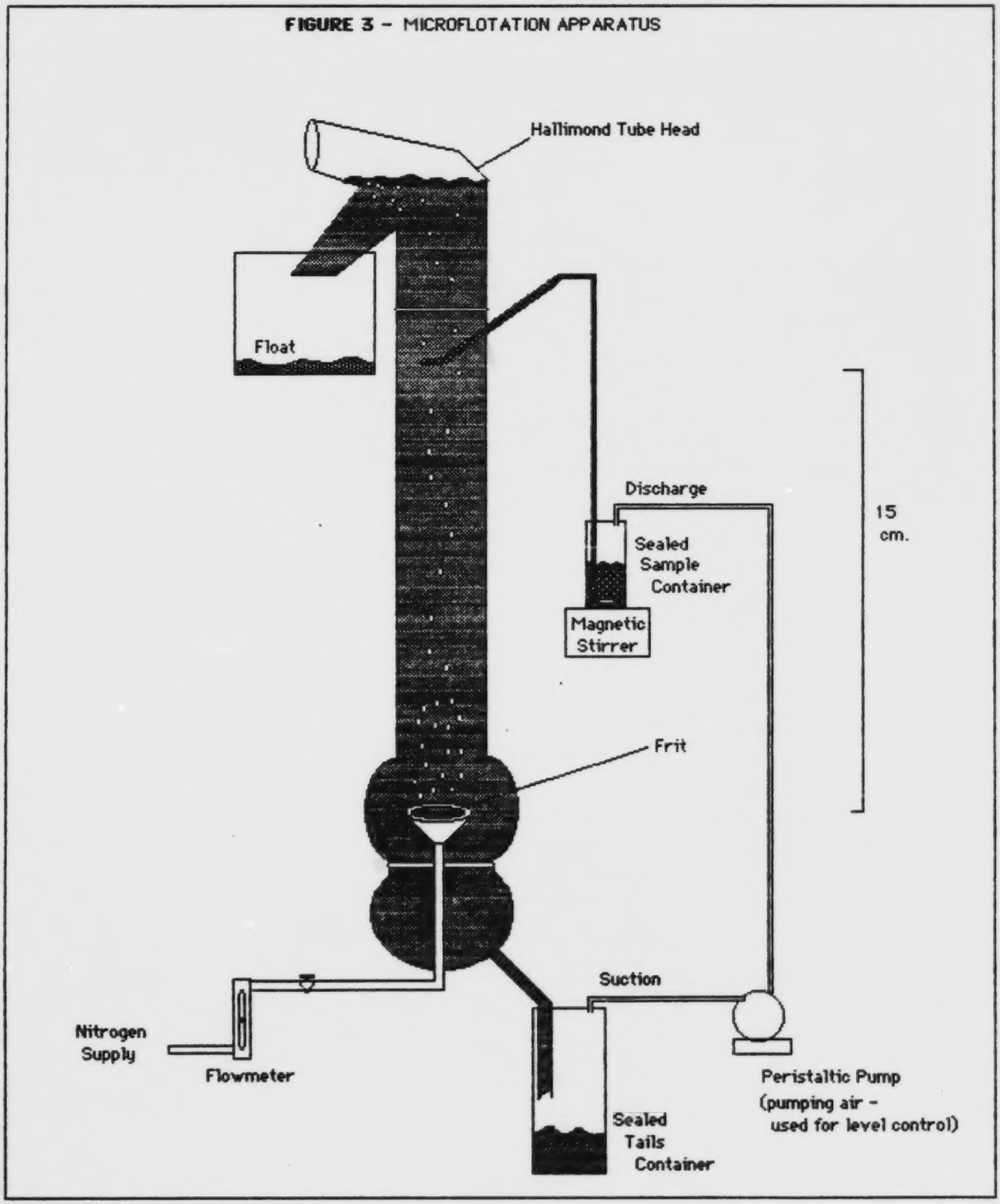


FIGURE 3 - MICROFLOTATION APPARATUS



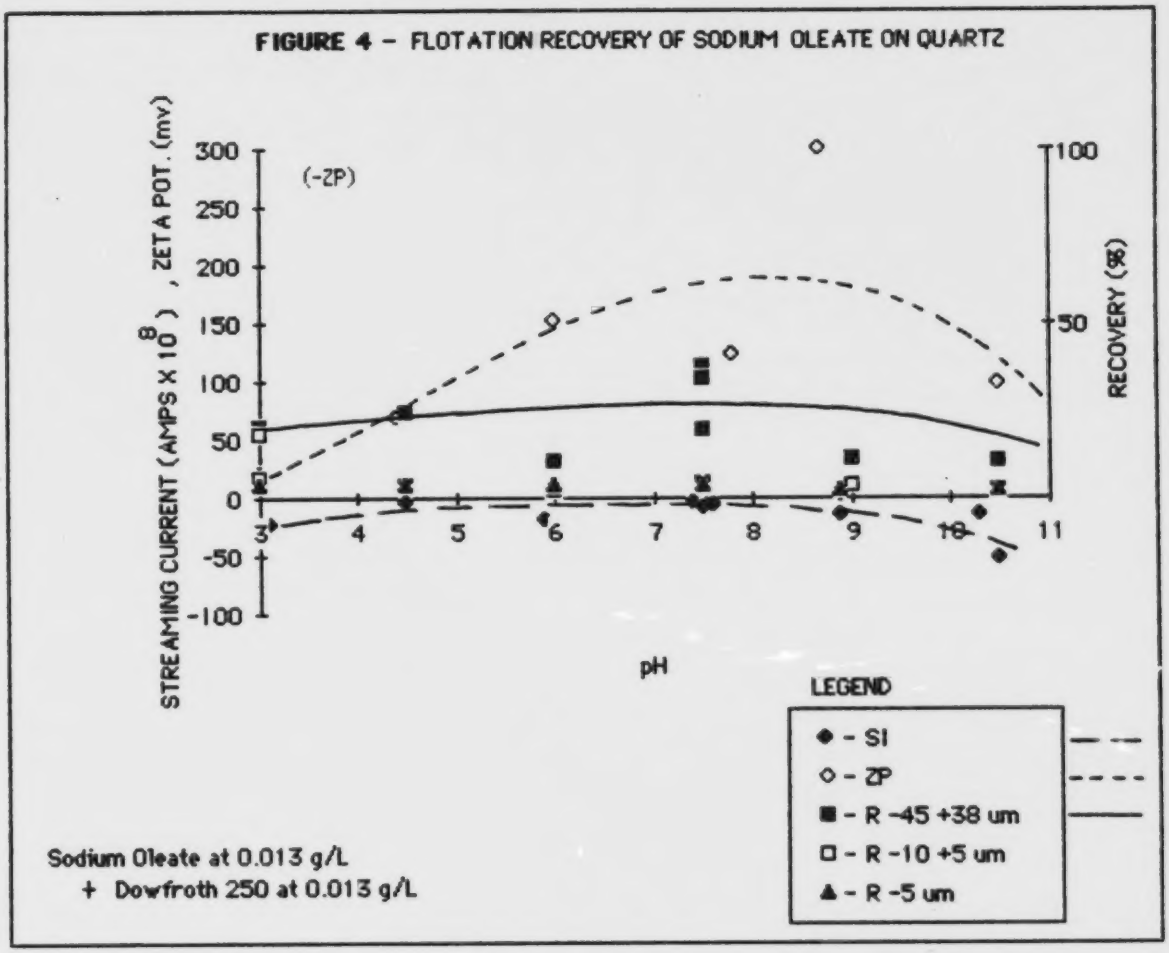


FIGURE 4 - FLOTATION RECOVERY OF SODIUM OLEATE ON QUARTZ
STREAMING CURRENT (AMPS X 10^8), ZETA POT. (mv)
(-ZP)
300
250
200
150
100
50
0
-50
-100
3
4
5
6
7
8
9
10
11
pH
100
50
RECOVERY (%)
LEGEND
◆ - SI
◇ - ZP
■ - R -45 +38 um
□ - R -10 +5 um
▲ - R -5 um
Sodium Oleate at 0.013 g/L
+ Dowfroth 250 at 0.013 g/L

FIGURE 5A – FLOTATION RECOVERY OF SODIUM LAURYL SULPHATE ON QUARTZ

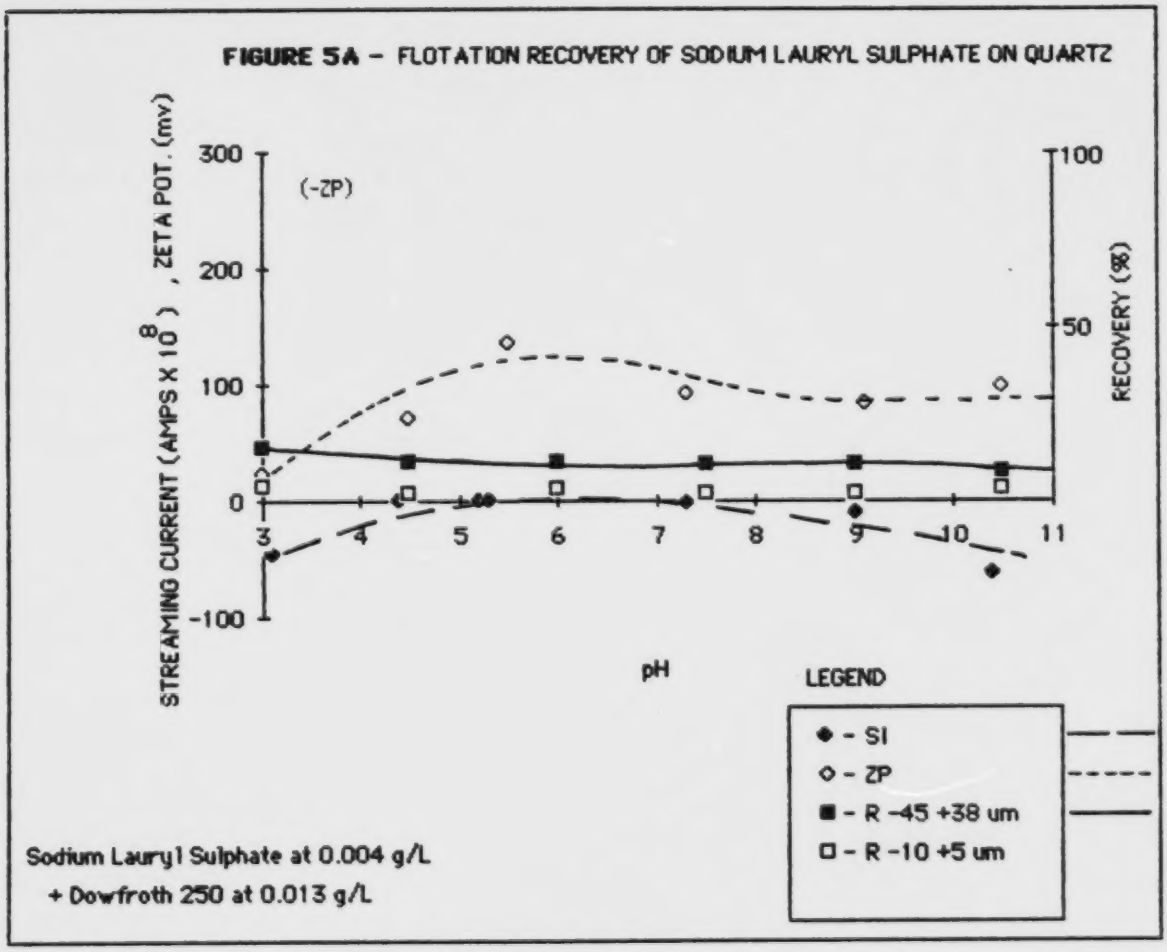


FIGURE 5B – FLOTATION RECOVERY OF SODIUM LAURYL SULPHATE ON QUARTZ

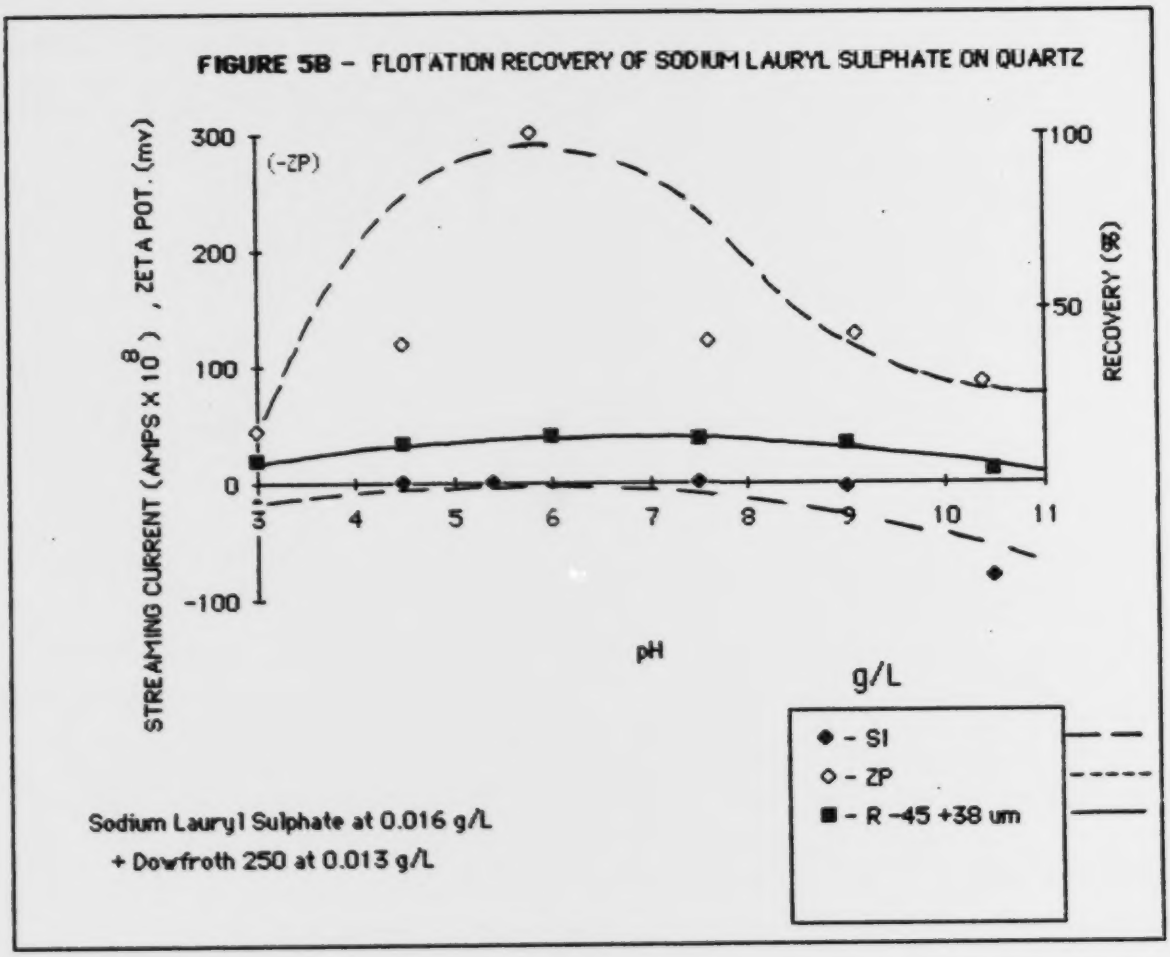


FIGURE 6 – FLOTATION RECOVERY OF BRIQUEST 281 ON QUARTZ

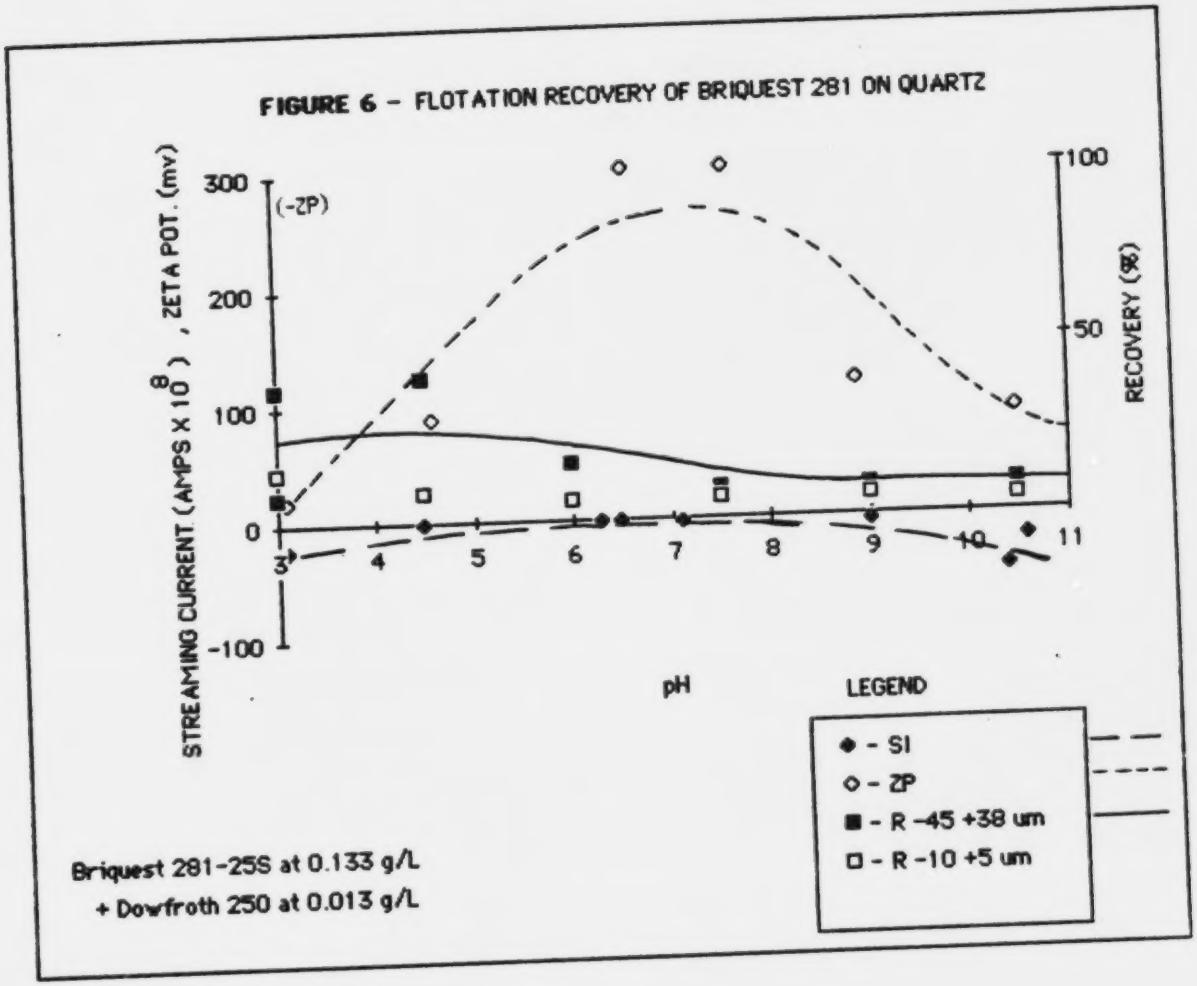
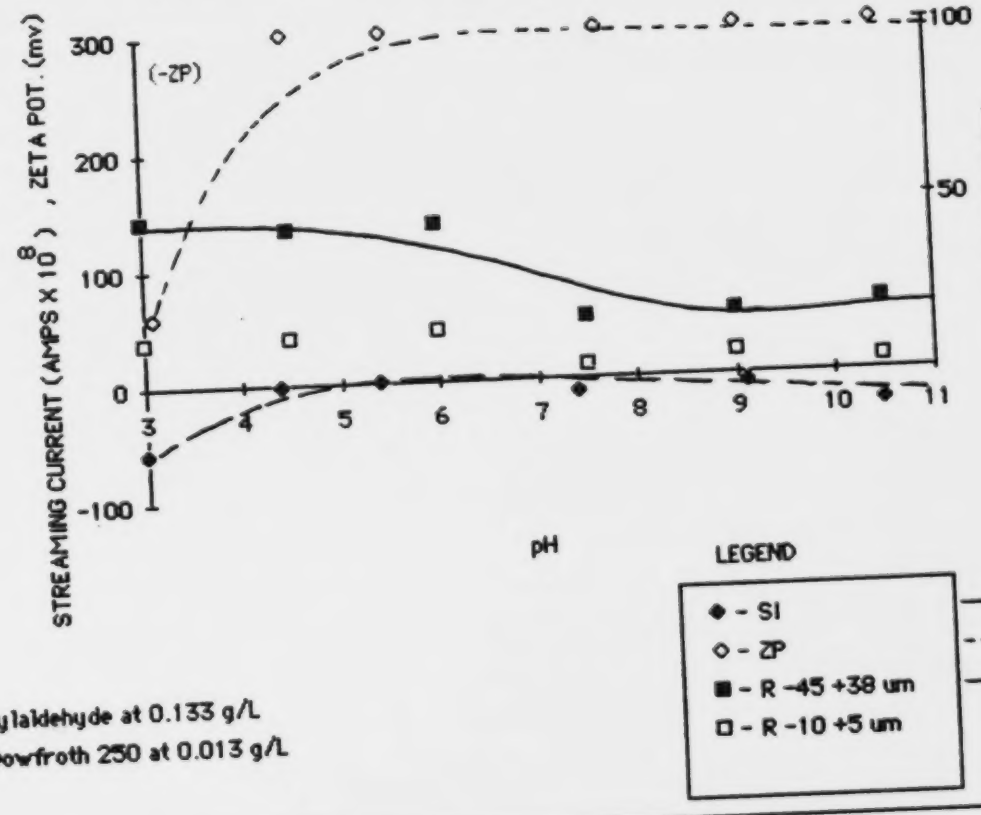


FIGURE 7 - FLOTATION RECOVERY OF SALICYLALDEHYDE ON QUARTZ



Salicylaldehyde at 0.133 g/L
+ Dowfroth 250 at 0.013 g/L

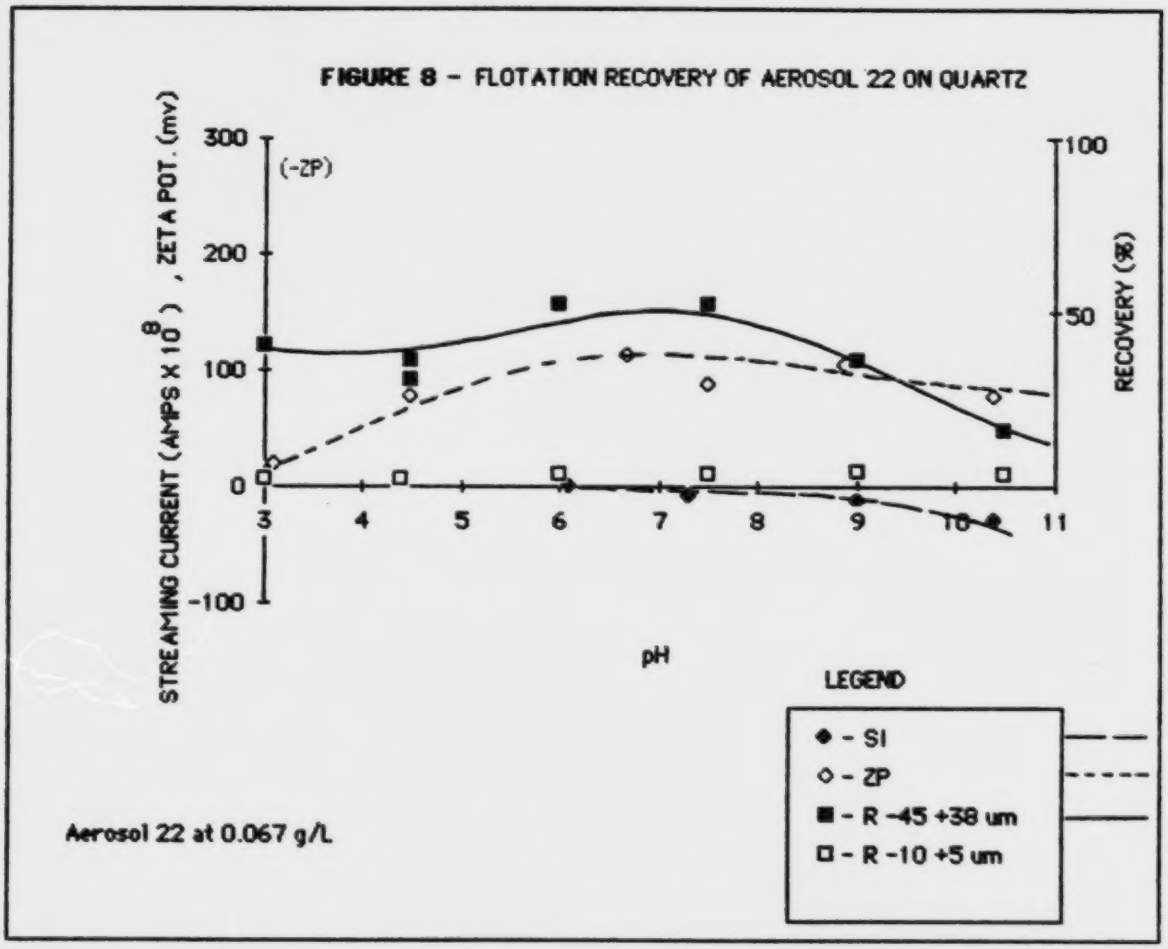


FIGURE 8 - FLOTATION RECOVERY OF AEROSOL 22 ON QUARTZ
STREAMING CURRENT (AMPS X 10^8), ZETA POT. (mv)
300
200
100
0
-100
(-ZP)
100
50
RECOVERY (%)
3
4
5
6
7
8
9
10
11
pH
LEGEND
◆ - SI
◇ - ZP
■ - R -45 +38 um
□ - R -10 +5 um
Aerosol 22 at 0.067 g/L

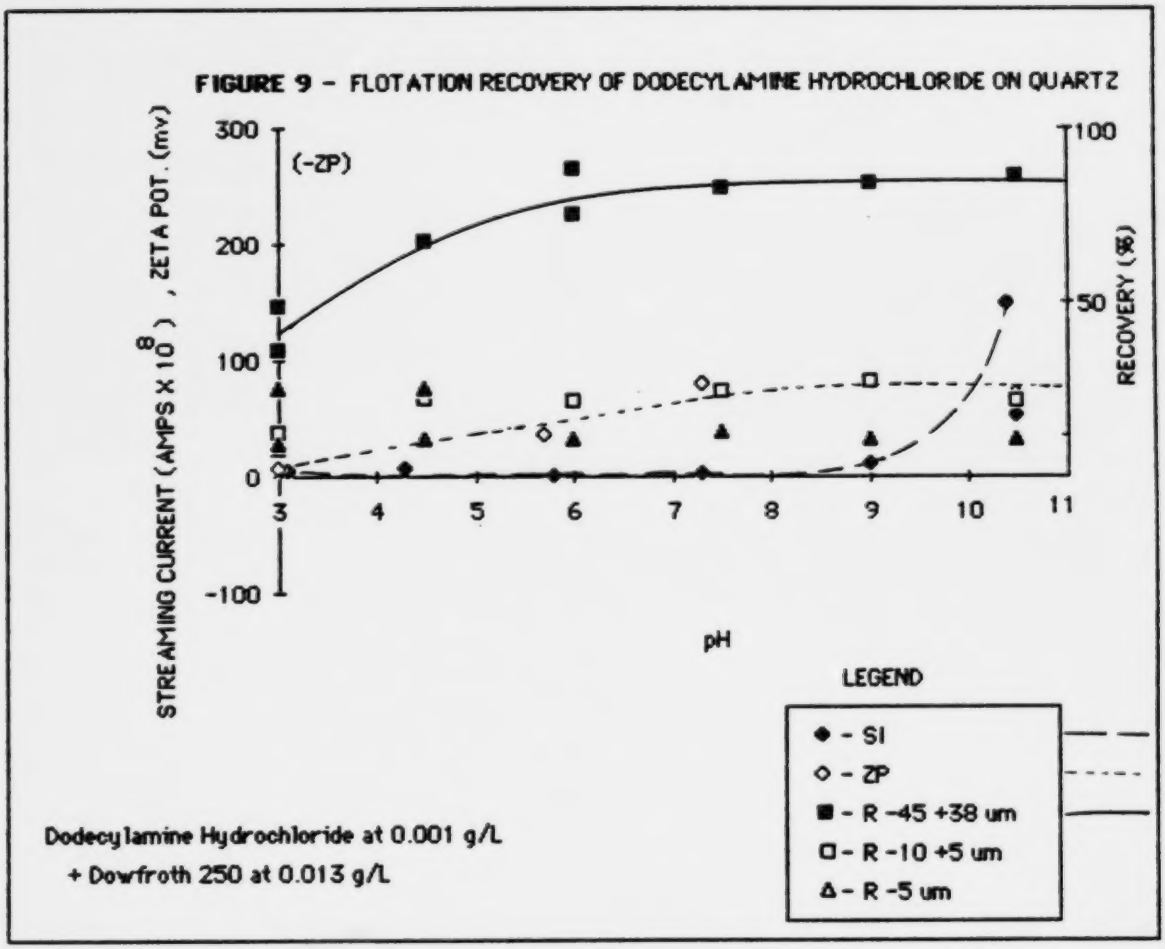


FIGURE 9 - FLOTATION RECOVERY OF DODECYLAMINE HYDROCHLORIDE ON QUARTZ
STREAMING CURRENT (AMPS X 10^8), ZETA POT. (mv)
(-ZP)
300
200
100
0
-100
3
4
5
6
7
8
9
10
11
pH
100
50
RECOVERY (%)
LEGEND
◆ - SI
◇ - ZP
■ - R -45 +38 um
□ - R -10 +5 um
△ - R -5 um
Dodecylamine Hydrochloride at 0.001 g/L
+ Dowfroth 250 at 0.013 g/L

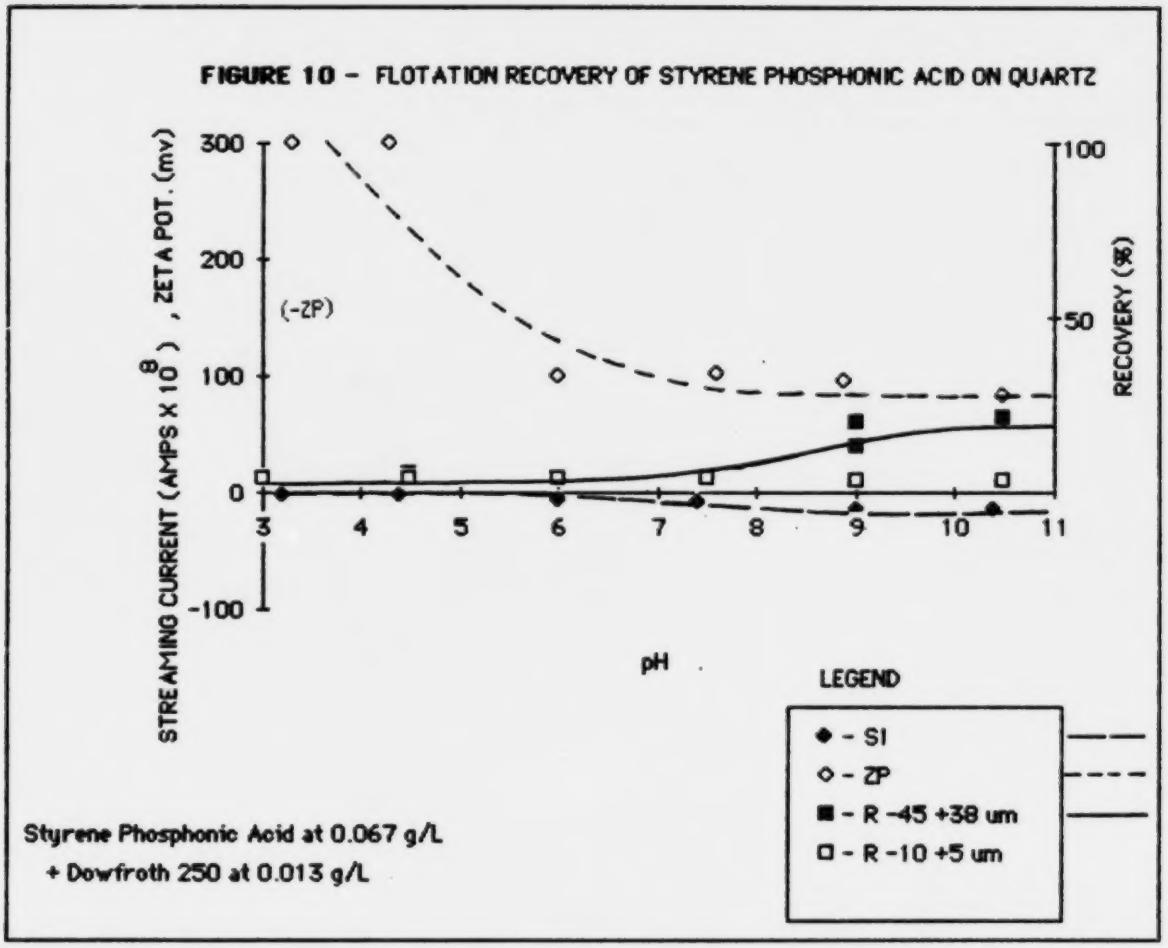


FIGURE 10 - FLOTATION RECOVERY OF STYRENE PHOSPHONIC ACID ON QUARTZ
STREAMING CURRENT (AMPS X 10^8), ZETA POT. (mv)
RECOVERY (%)
300
200
100
0
-100
100
50
(-ZP)
3
4
5
6
7
8
9
10
11
pH
LEGEND
◆ - SI
◇ - ZP
■ - R -45 +38 um
□ - R -10 +5 um
Styrene Phosphonic Acid at 0.067 g/L
+ Dowfroth 250 at 0.013 g/L

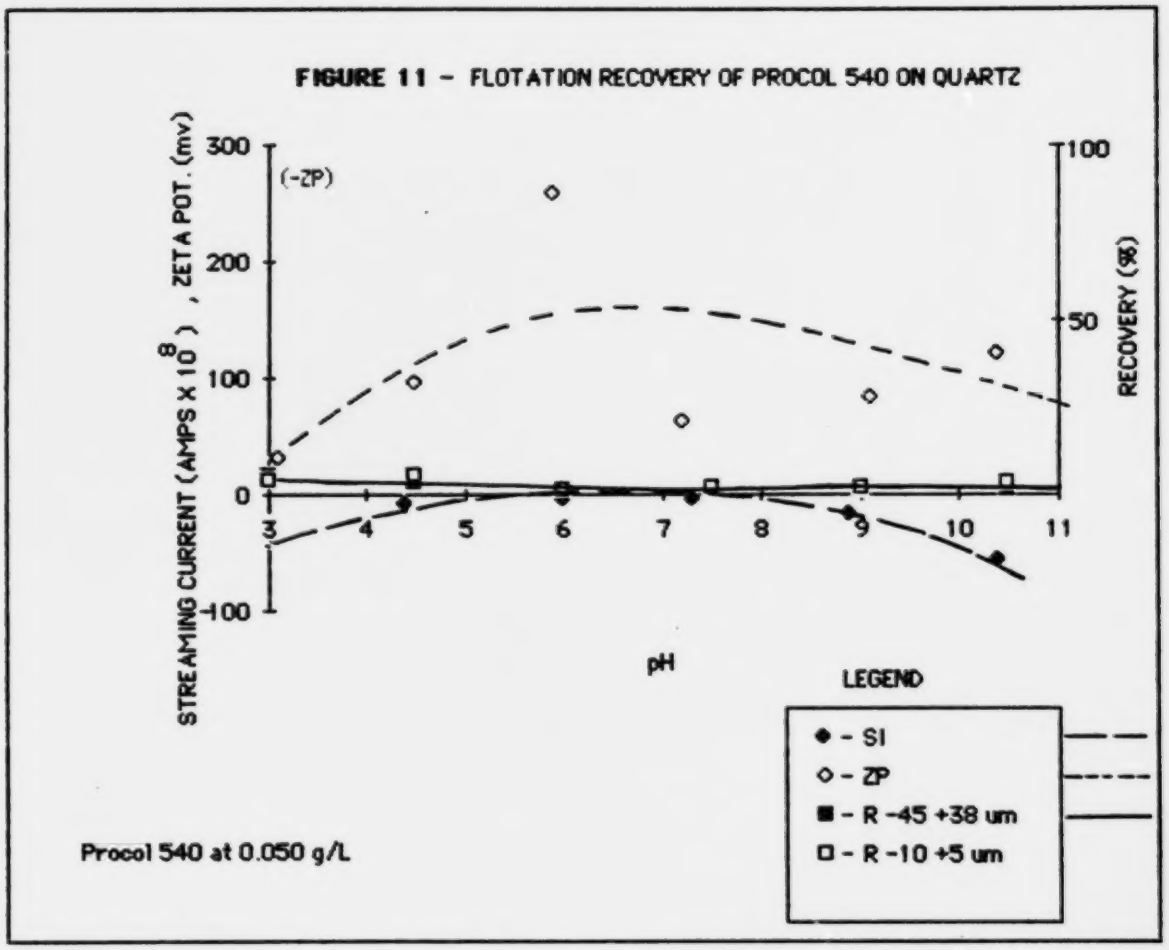


FIGURE 11 - FLOTATION RECOVERY OF PROCOL 540 ON QUARTZ
STREAMING CURRENT (AMPS X 10^8) , ZETA POT. (mv)
(-ZP)
300
200
100
0
-100
100
50
RECOVERY (%)
3
4
5
6
7
8
9
10
11
pH
LEGEND
◆ - SI
◇ - ZP
■ - R -45 +38 um
□ - R -10 +5 um
Procol 540 at 0.050 g/L

FIGURE 12 - FLOTATION RECOVERY OF SODIUM OLEATE ON CASSITERITE

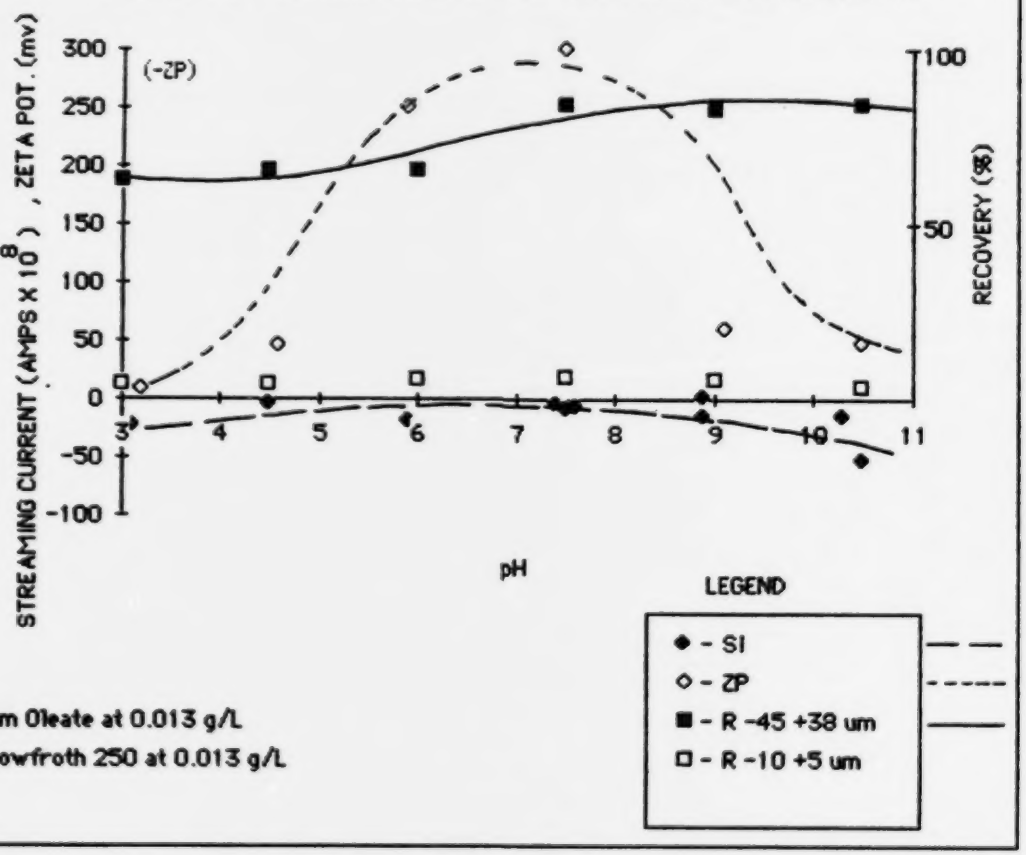
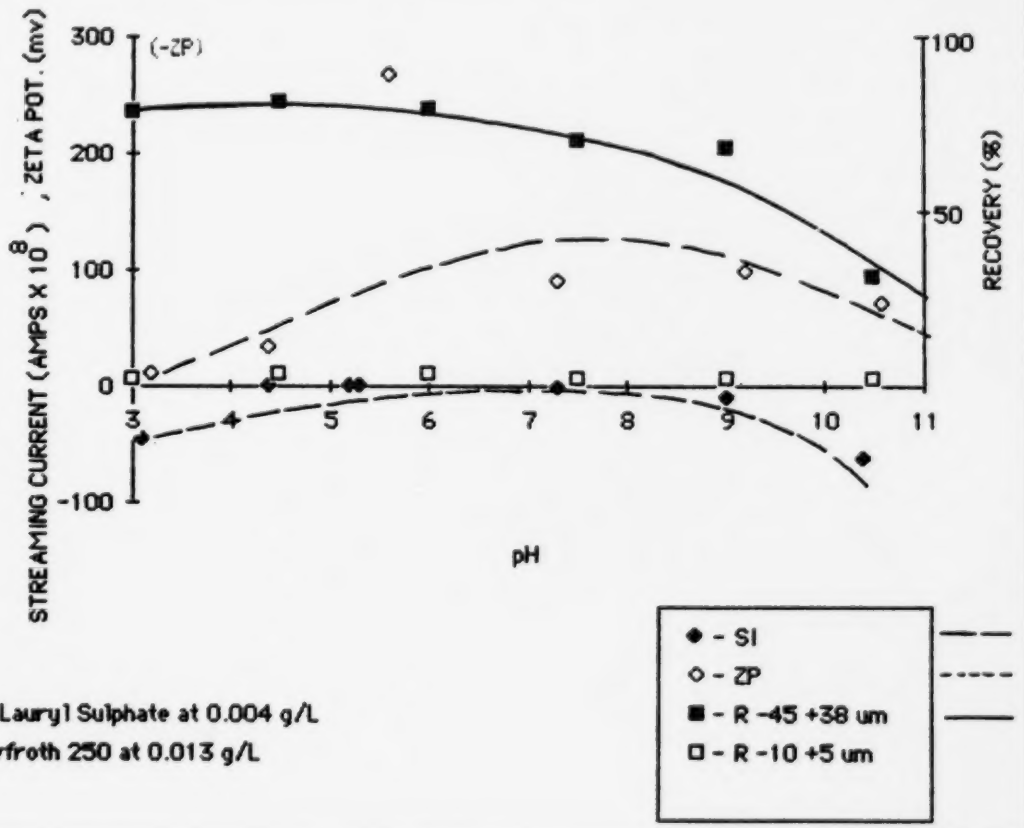


FIGURE 13 - FLOTATION RECOVERY OF SODIUM LAURYL SULPHATE ON CASSITERITE



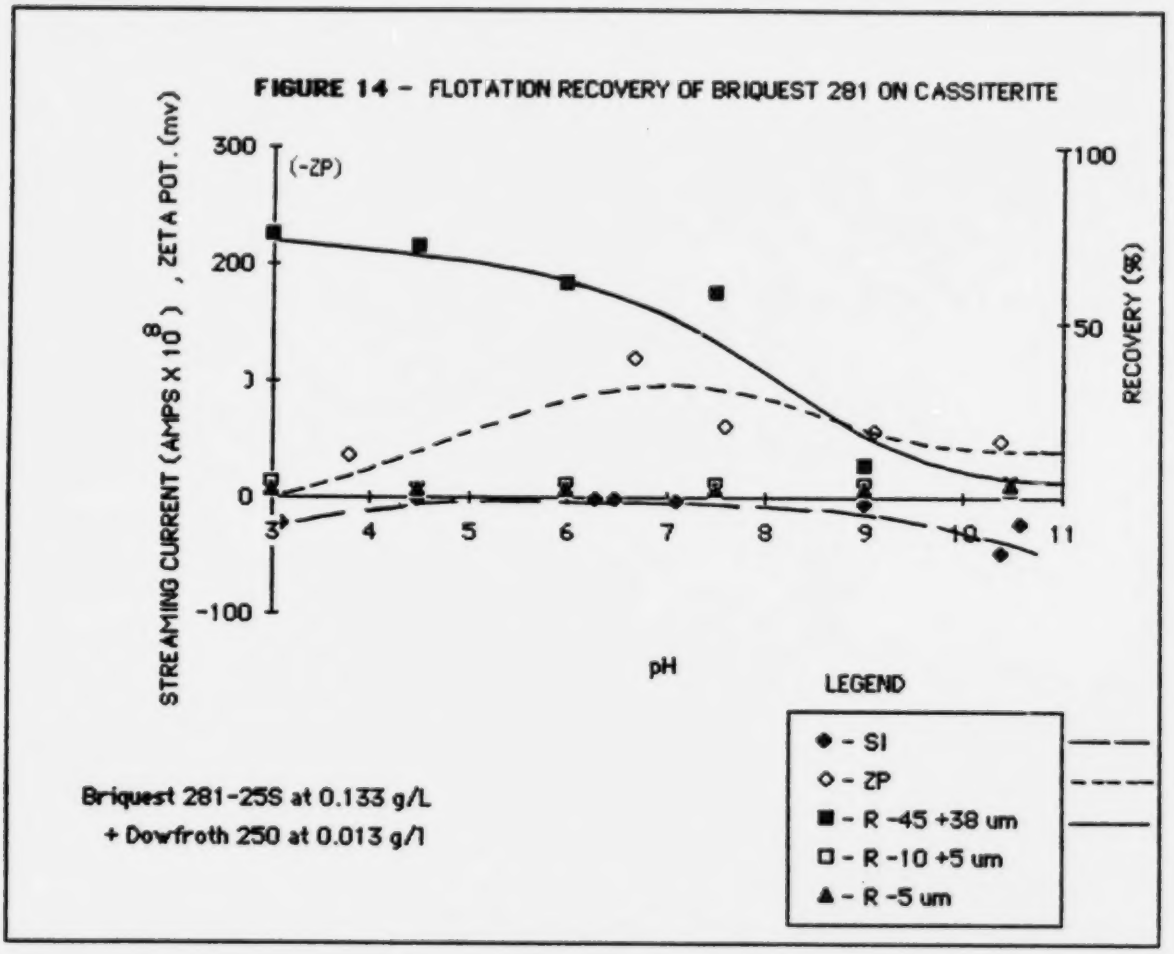


FIGURE 14 - FLOTATION RECOVERY OF BRIQUEST 281 ON CASSITERITE
STREAMING CURRENT (AMPS X 10^8), ZETA POT. (mv)
300
200
0
-100
(-ZP)
100
50
RECOVERY (%)
3
4
5
6
7
8
9
10
11
pH
LEGEND
◆ - SI
◇ - ZP
■ - R -45 +38 um
□ - R -10 +5 um
▲ - R -5 um
Briquest 281-25S at 0.133 g/L
+ Dowfroth 250 at 0.013 g/l

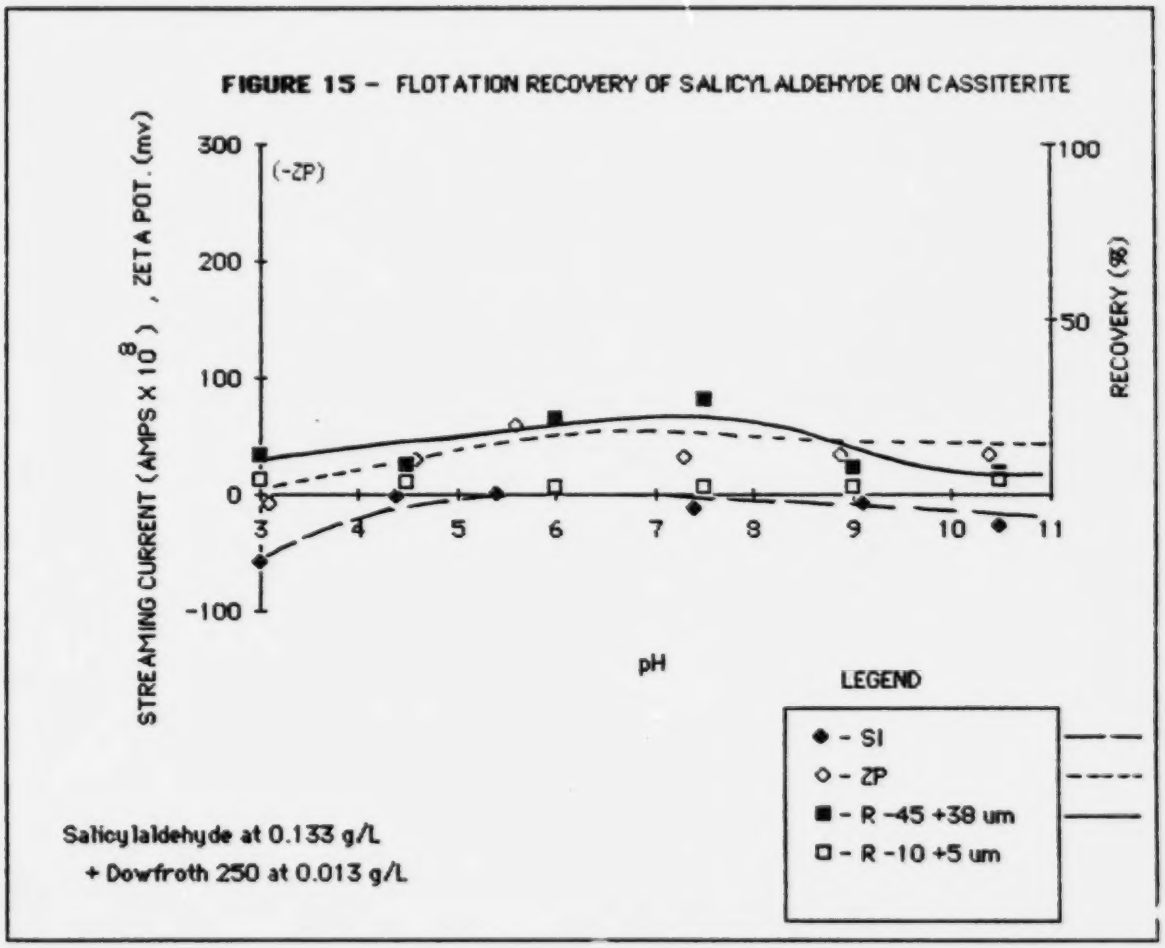
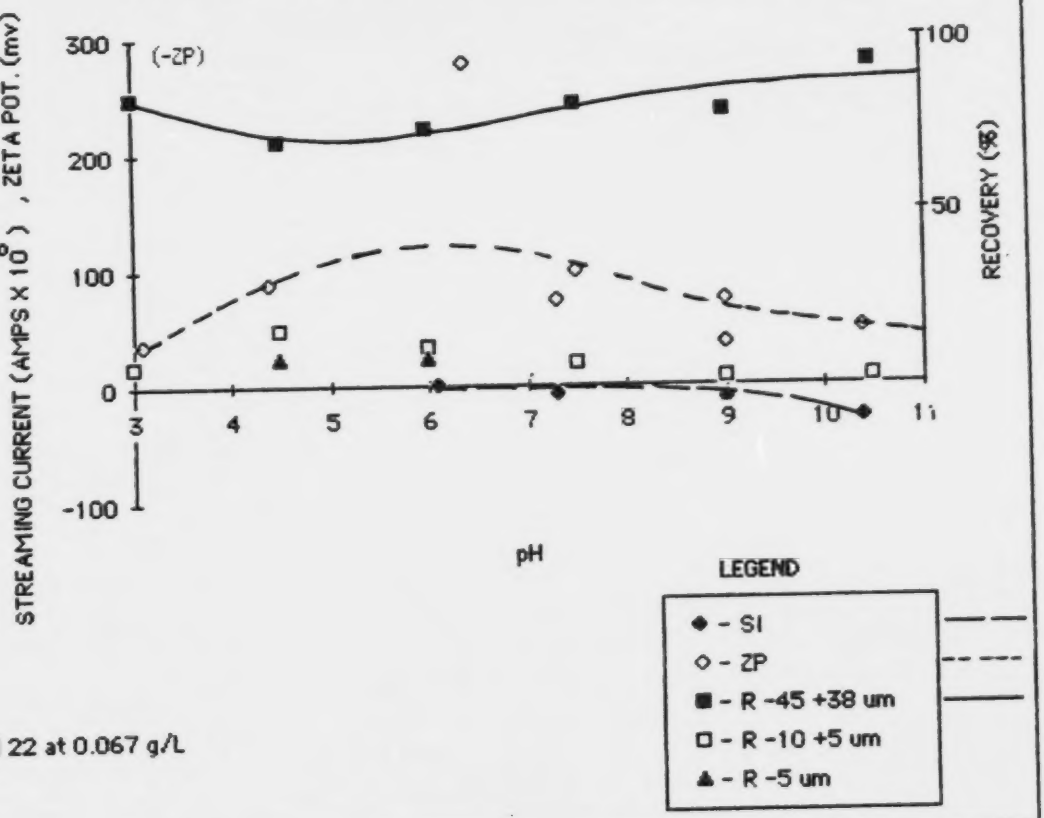


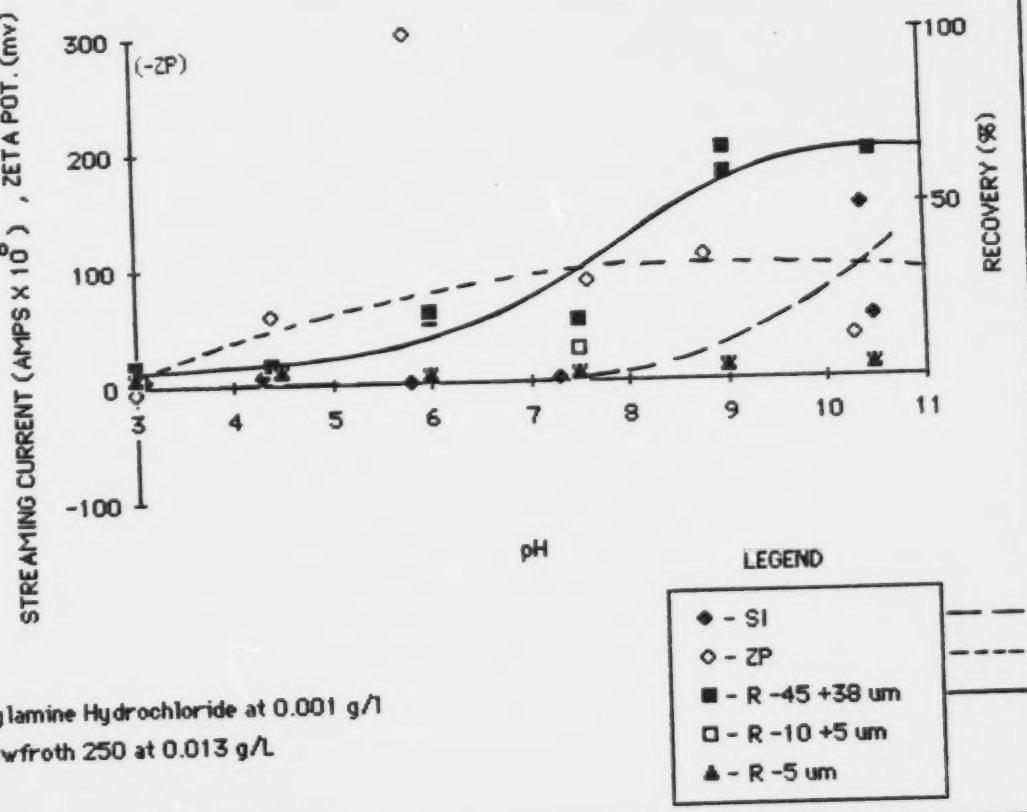
FIGURE 15 - FLOTATION RECOVERY OF SALICYLALDEHYDE ON CASSITERITE
STREAMING CURRENT (AMPS X 10^8), ZETA POT. (mv)
(-ZP)
300
200
100
0
-100
100
50
RECOVERY (%)
3
4
5
6
7
8
9
10
11
pH
LEGEND
◆ - SI
◇ - ZP
■ - R -45 +38 um
□ - R -10 +5 um
Salicylaldehyde at 0.133 g/L
+ Dowfroth 250 at 0.013 g/L

FIGURE 16 – FLOTATION RECOVERY OF AEROSOL 22 ON CASSITERITE



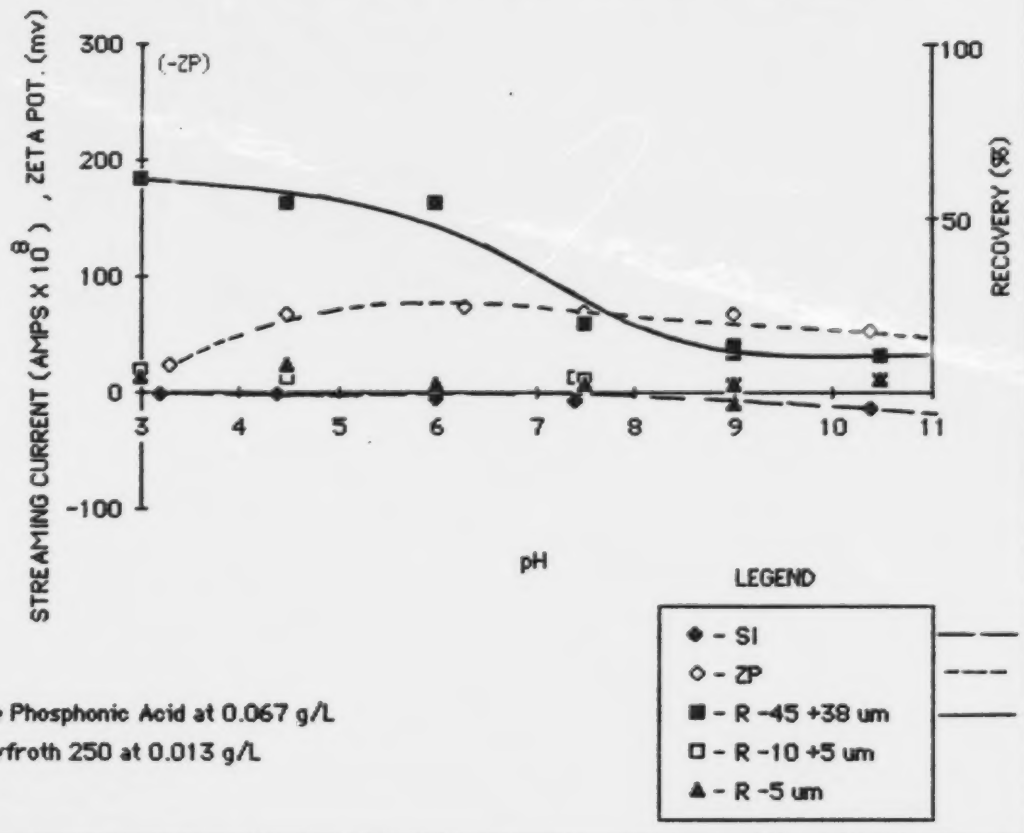
Aerosol 22 at 0.067 g/L

FIGURE 17 – FLOTATION RECOVERY OF DODECYLAMINE HYDROCHLORIDE ON CASSITERITE



Dodecylamine Hydrochloride at 0.001 g/l
+ Dowfroth 250 at 0.013 g/L

FIGURE 18 - FLOTATION RECOVERY OF STYRENE PHOSPHONIC ACID ON CASSITERITE



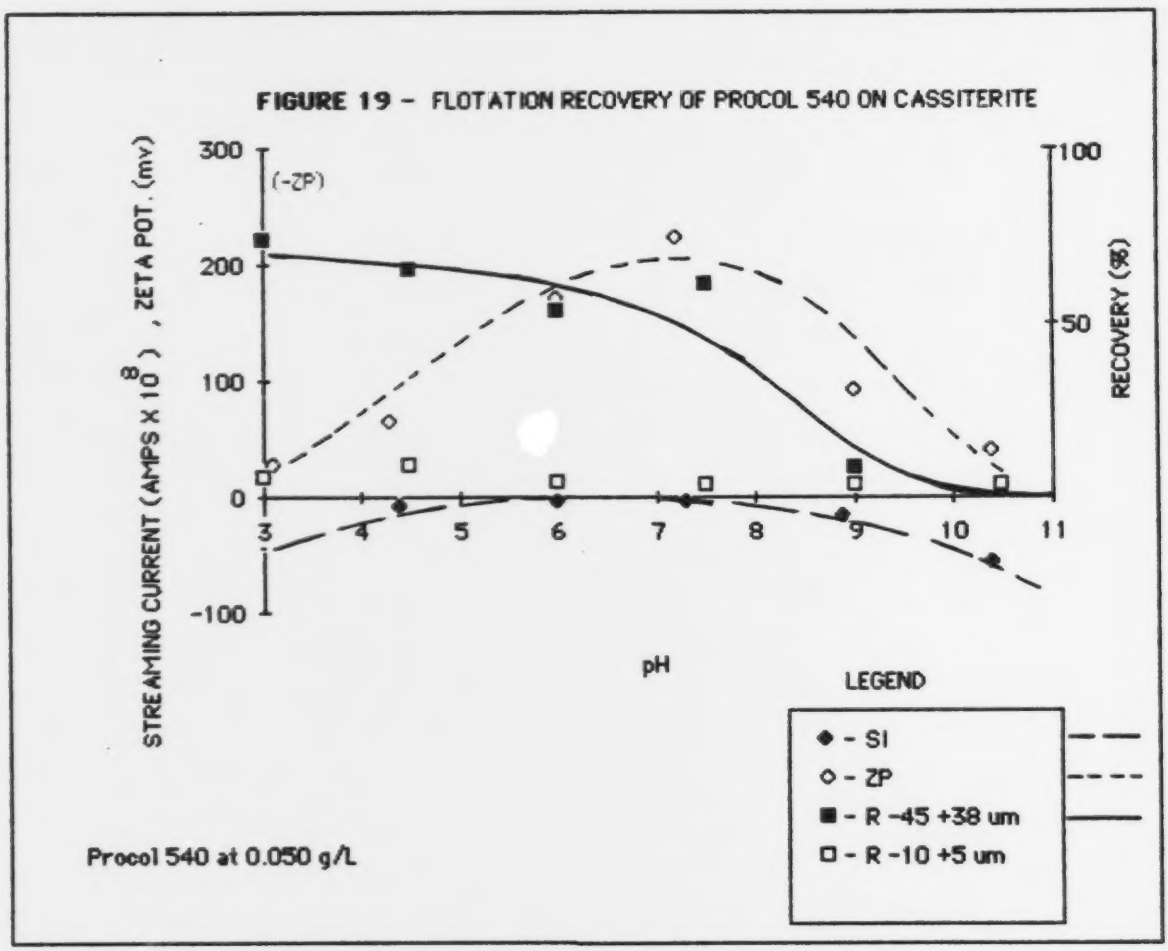


FIGURE 19 - FLOTATION RECOVERY OF PROCOL 540 ON CASSITERITE
STREAMING CURRENT (AMPS X 10^8), ZETA POT. (mv)
(-ZP)
300
200
100
0
-100
3
4
5
6
7
8
9
10
11
pH
100
50
RECOVERY (%)
LEGEND
◆ - SI
◇ - ZP
■ - R -45 +38 um
□ - R -10 +5 um
Procol 540 at 0.050 g/L

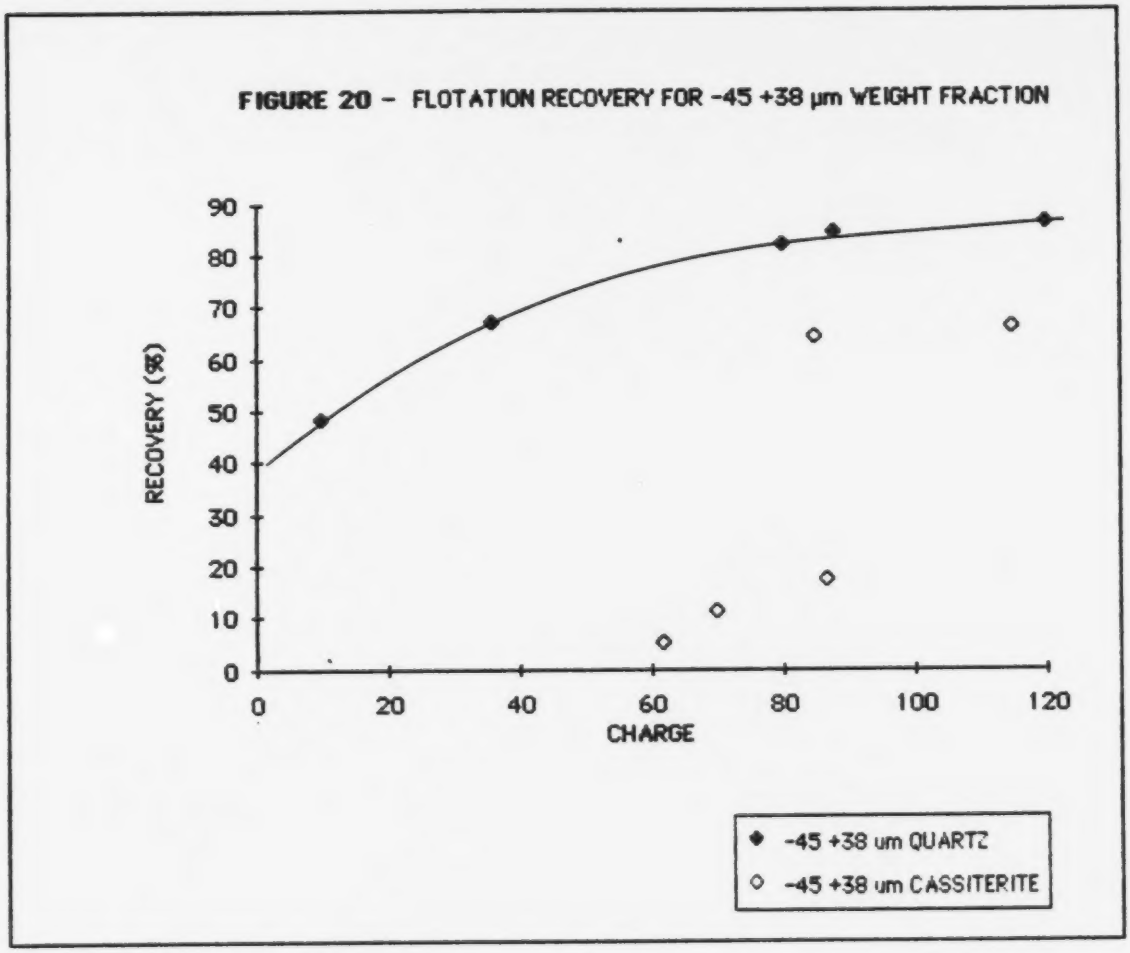


FIGURE 20 - FLOTATION RECOVERY FOR -45 +38 µm WEIGHT FRACTION
RECOVERY (%)
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
CHARGE
-45 +38 um QUARTZ
-45 +38 um CASSITERITE

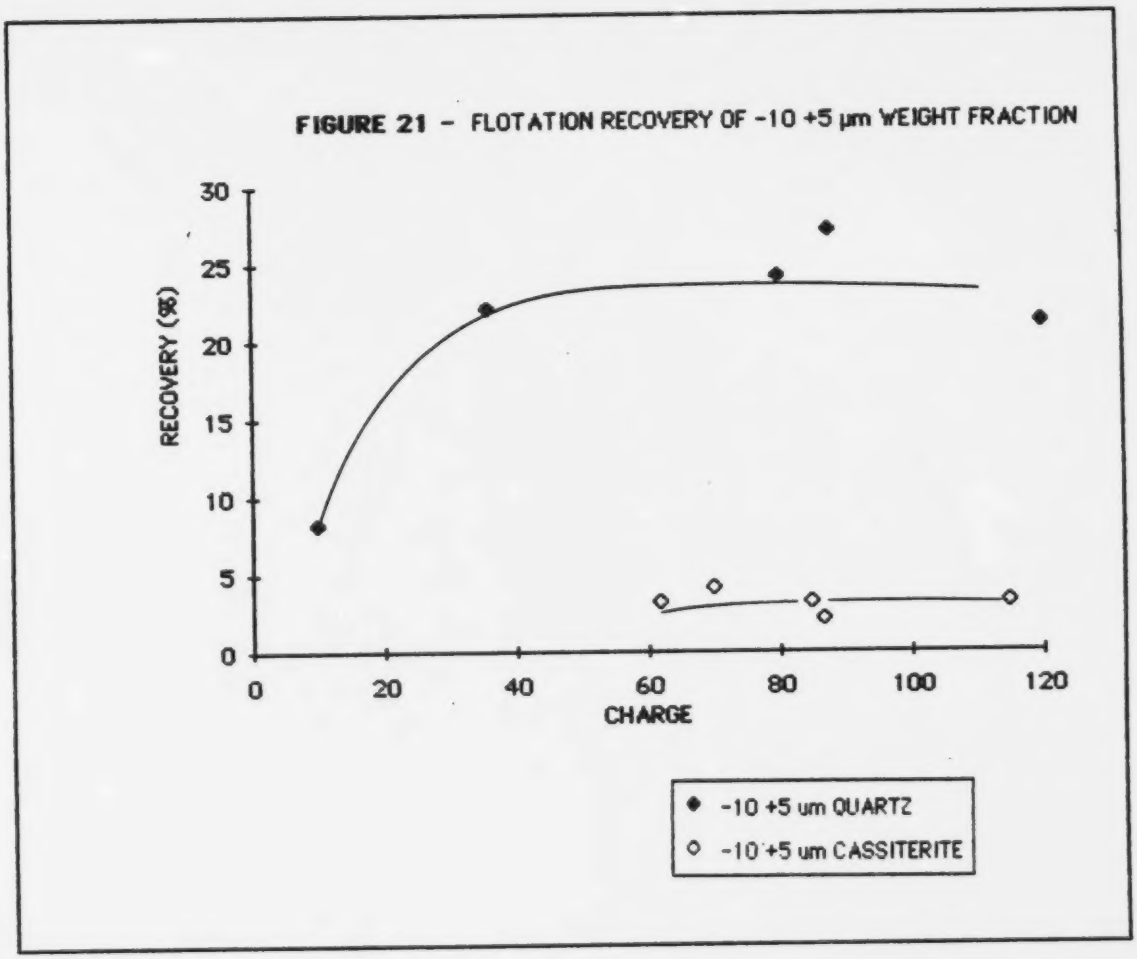


FIGURE 21 - FLOTATION RECOVERY OF -10 +5 µm WEIGHT FRACTION
RECOVERY (%)
30
25
20
15
10
5
0
0
20
40
60
80
100
120
CHARGE
-10 +5 um QUARTZ
-10 +5 um CASSITERITE

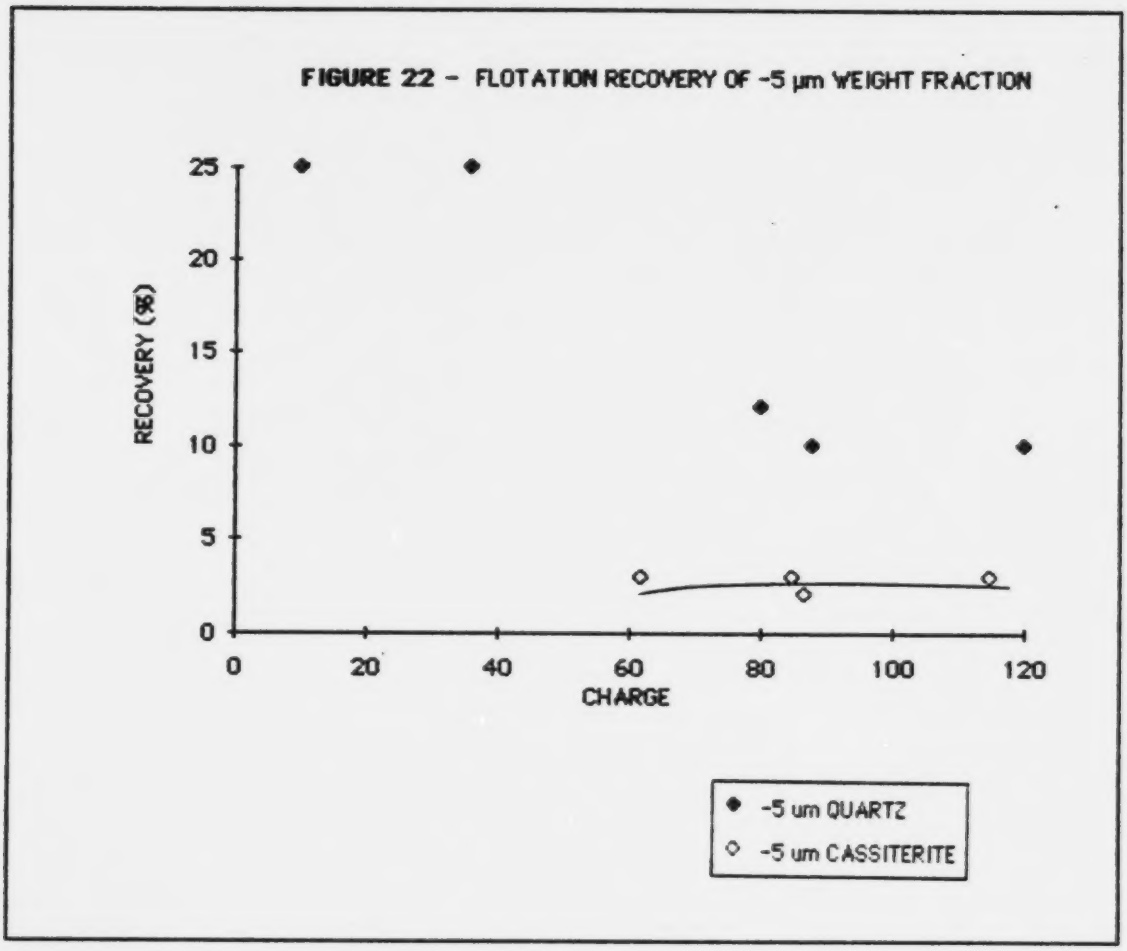


FIGURE 22 - FLOTATION RECOVERY OF -5 µm WEIGHT FRACTION
RECOVERY (%)
25
20
15
10
5
0
0
20
40
60
80
100
120
CHARGE
-5 um QUARTZ
-5 um CASSITERITE

FIGURE 23 - FLOTATION OF -45 +38 µm QUARTZ VERSUS STREAMING CURRENT

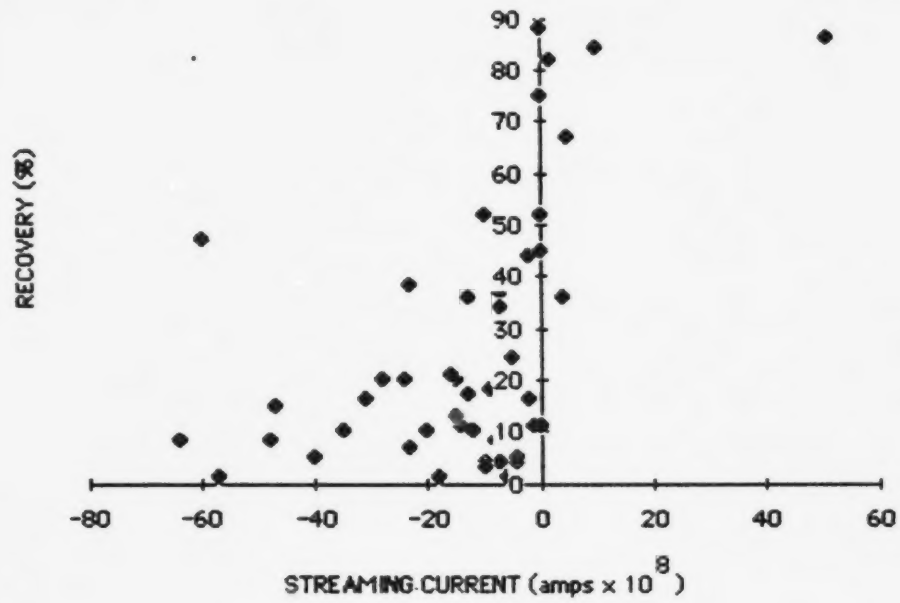


FIGURE 24 - FLOTATION OF -45 +38 µm CASSITERITE VERSUS STREAMING CURRENT

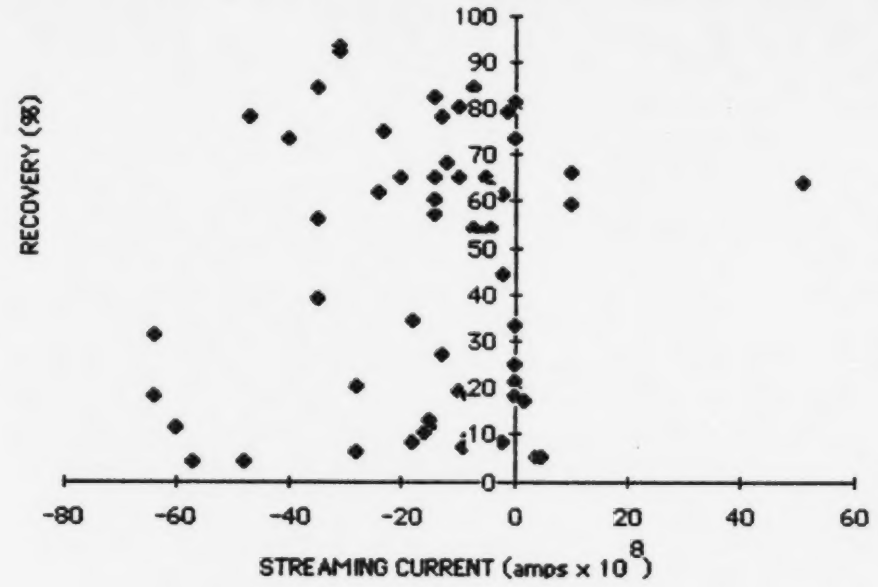


FIGURE 25 – FLOTATION OF -45 +38 µm QUARTZ VERSUS ZETA POTENTIAL

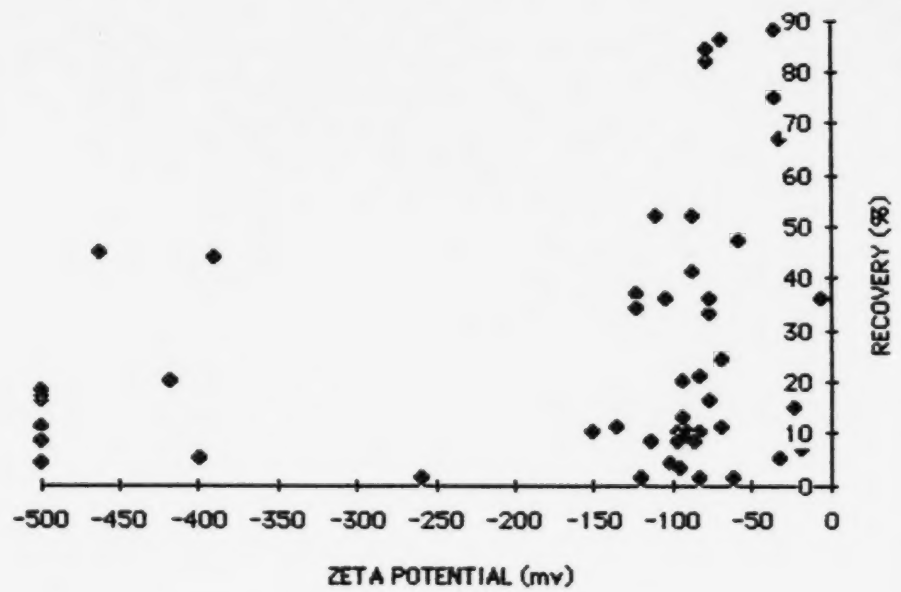


FIGURE 26 - FLOTATION OF -45 +38 µm CASSITERITE VERSUS ZETA POTENTIAL

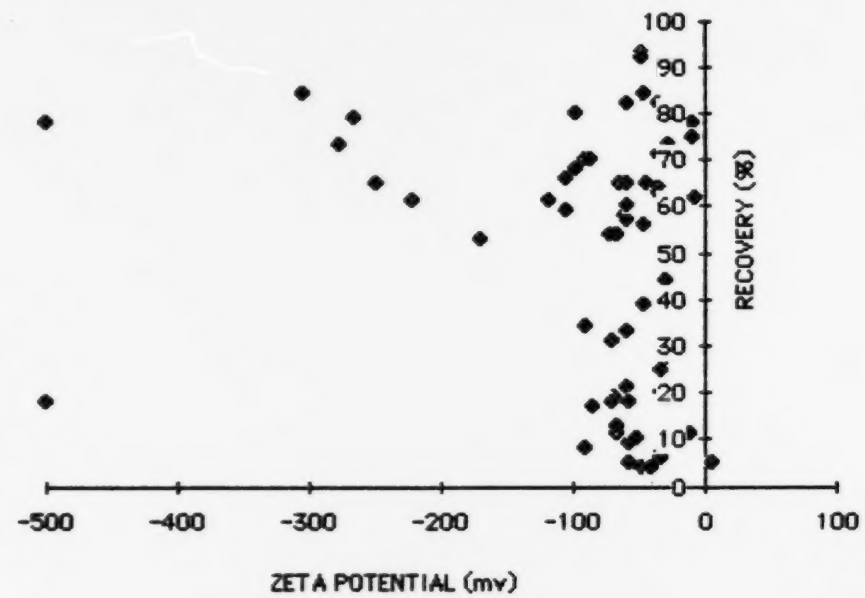
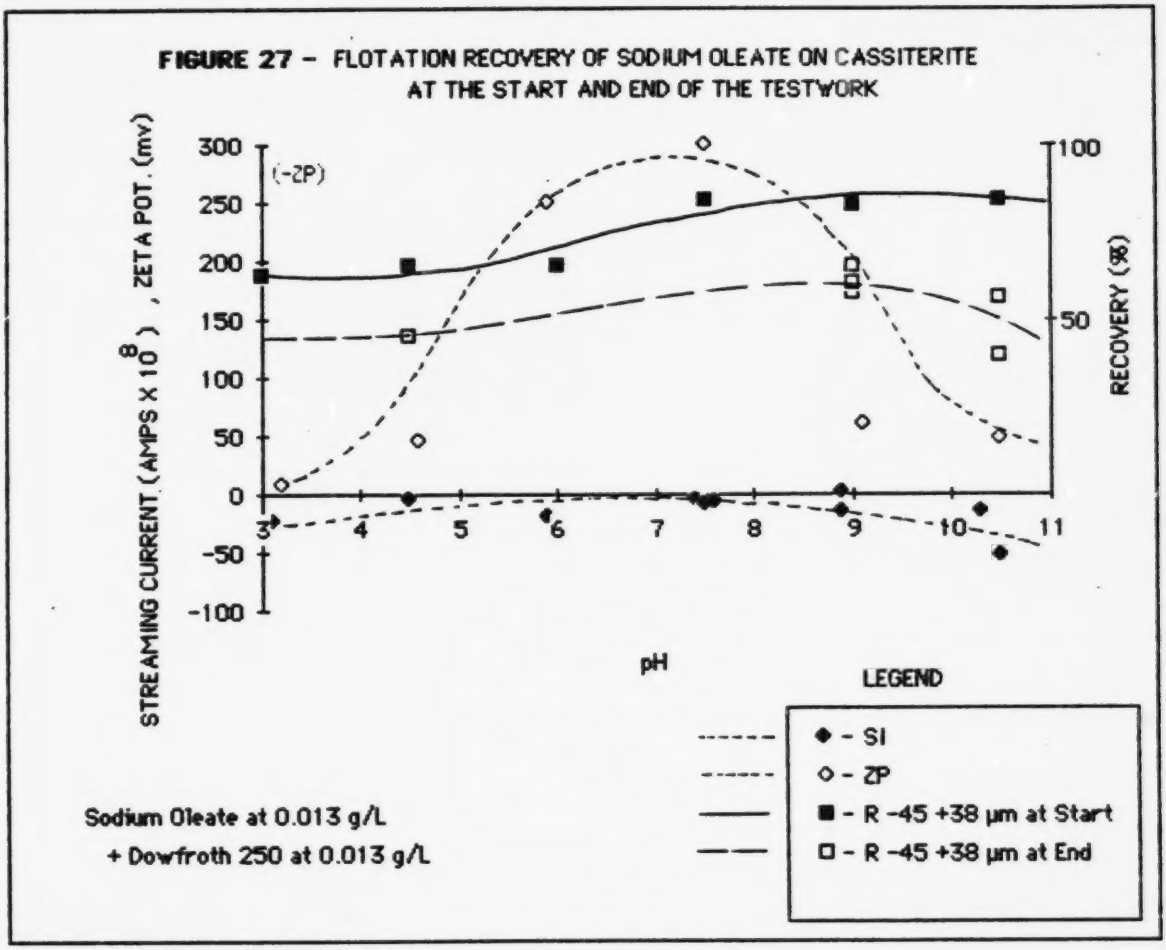


FIGURE 27 - FLOTATION RECOVERY OF SODIUM OLEATE ON CASSITERITE AT THE START AND END OF THE TESTWORK



APPENDIX A

STREAMING CURRENT TESTWORK RESULTS

APPENDIX A - STREAMING CURRENT

Figures A1-A8 show the streaming current versus pH for each of the eight collectors tested. These graphs do show scatter in the raw data however the smoothed curves for each of the three concentrations have a similar shape giving some confidence in the reliability of the data. The curves were drawn by performing cubic or quadratic regressions on each data set.

The raw data are presented in tabular form in APPENDIX D.

EXAMPLE STREAMING CURRENT CALCULATION

Sodium Oleate at 0.007 g/L (~10 g/MT) and
Dowfroth 250 at 0.013 g/L

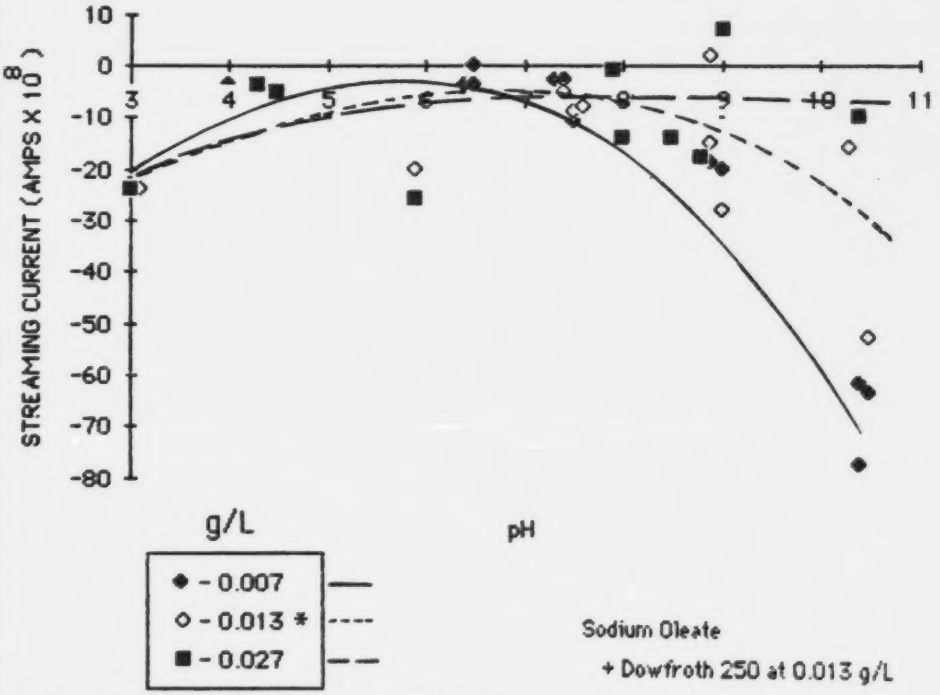
pH = 10.4 measured Resistance of cell R_{cell} = 19,200 ohms

therefore set external resistance to $R_{ext} = .02 * R_{cell} = 383$ ohms

measured V = -0.300 millivolts

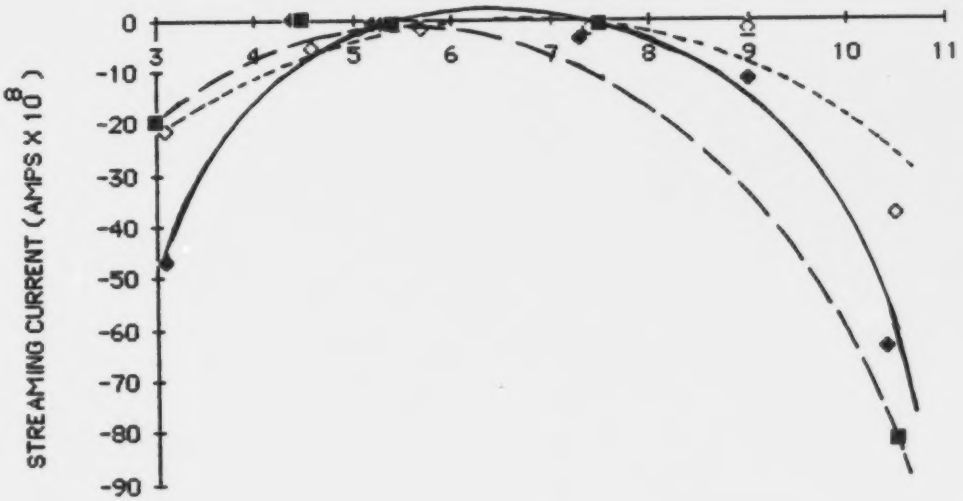
$$I = \frac{V}{R} = \frac{-0.300 \times 10^{-3}}{383} = -78 \times 10^{-8} \text{ amps}$$

FIGURE A1 – STREAMING CURRENT FOR SODIUM OLEATE



* - concentration used for microflotation runs

FIGURE A2 – STREAMING CURRENT FOR SODIUM LAURYL SULPHATE



g/L

◆ – 0.004 *

◇ – 0.008

■ – 0.016

Sodium Lauryl Sulphate

+ Dowfroth 250 at 0.013 g/l

* – concentration used for microflotation runs

FIGURE A3 – STREAMING CURRENT FOR BRIQUEST 281-25S

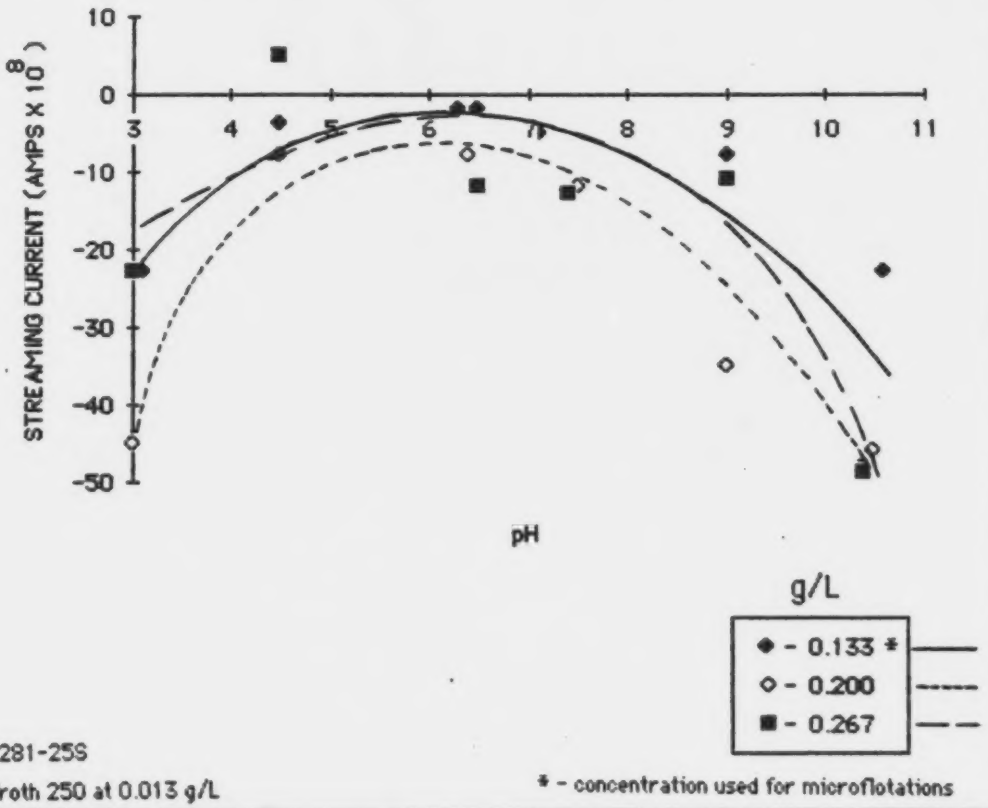


FIGURE A4 - STREAMING CURRENT FOR SALICYLALDEHYDE

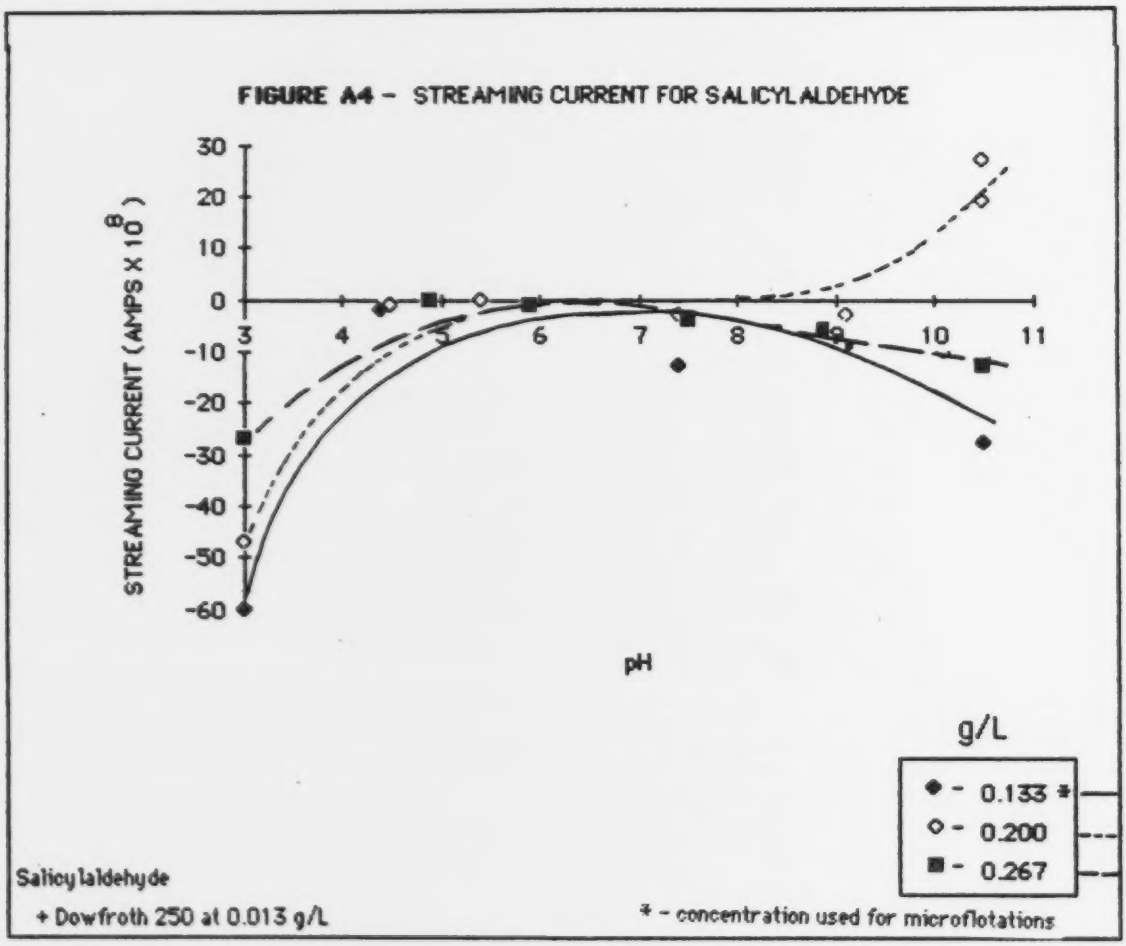
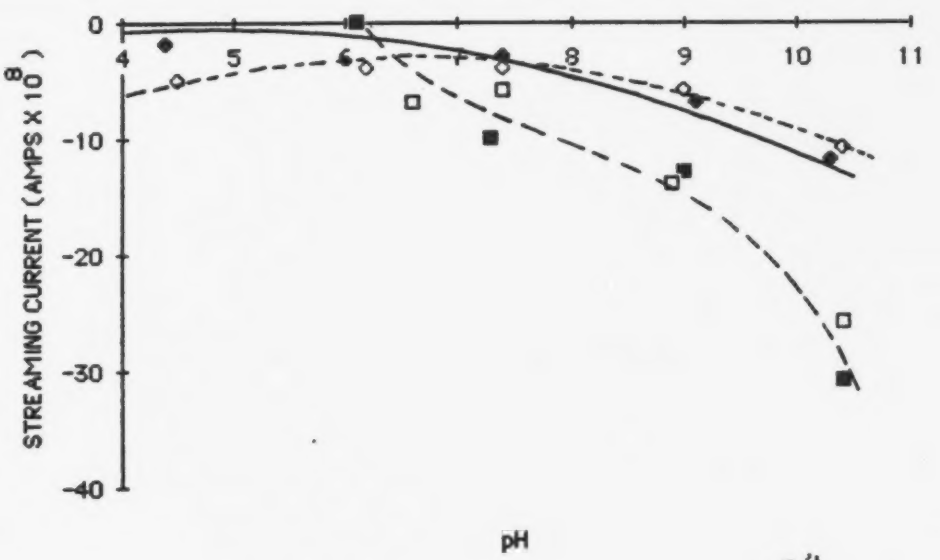


FIGURE A5a – STREAMING CURRENT OF AEROSOL 22



g/L

◆ – 0.017 ——

◇ – 0.033 – – –

■ – 0.067 * — — —

□ – 0.133

Aerosol 22 no DOWFROTH

* – concentration used for microflotations

FIGURE A5b – STREAMING CURRENT OF AEROSOL 22

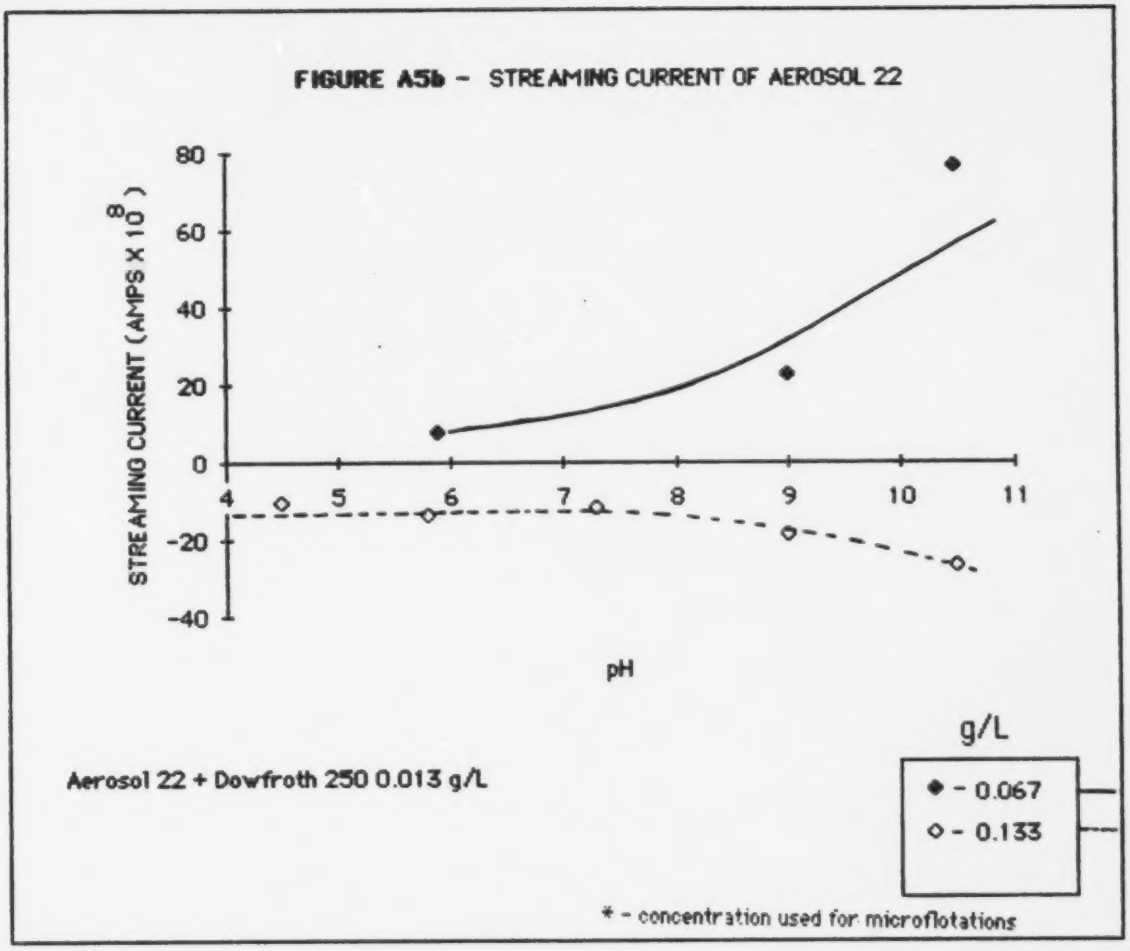
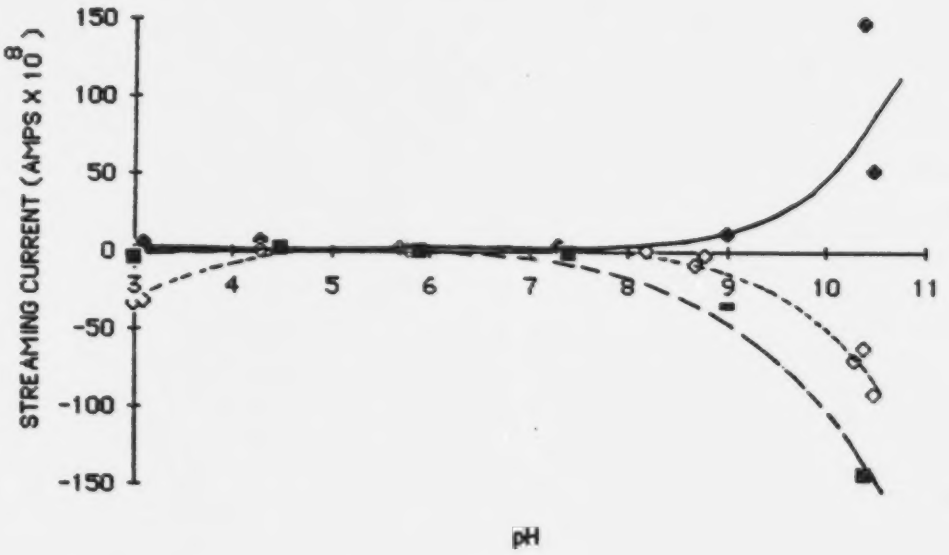


FIGURE A6a – STREAMING CURRENT OF DODECYLAMINE HYDROCHLORIDE



Dodecylamine Hydrochloride
+ Dowfroth 250 at 0.013 g/L

g/L
◆ - 0.001 *
◇ - 0.009
■ - 0.018

* - concentration used for microflotations

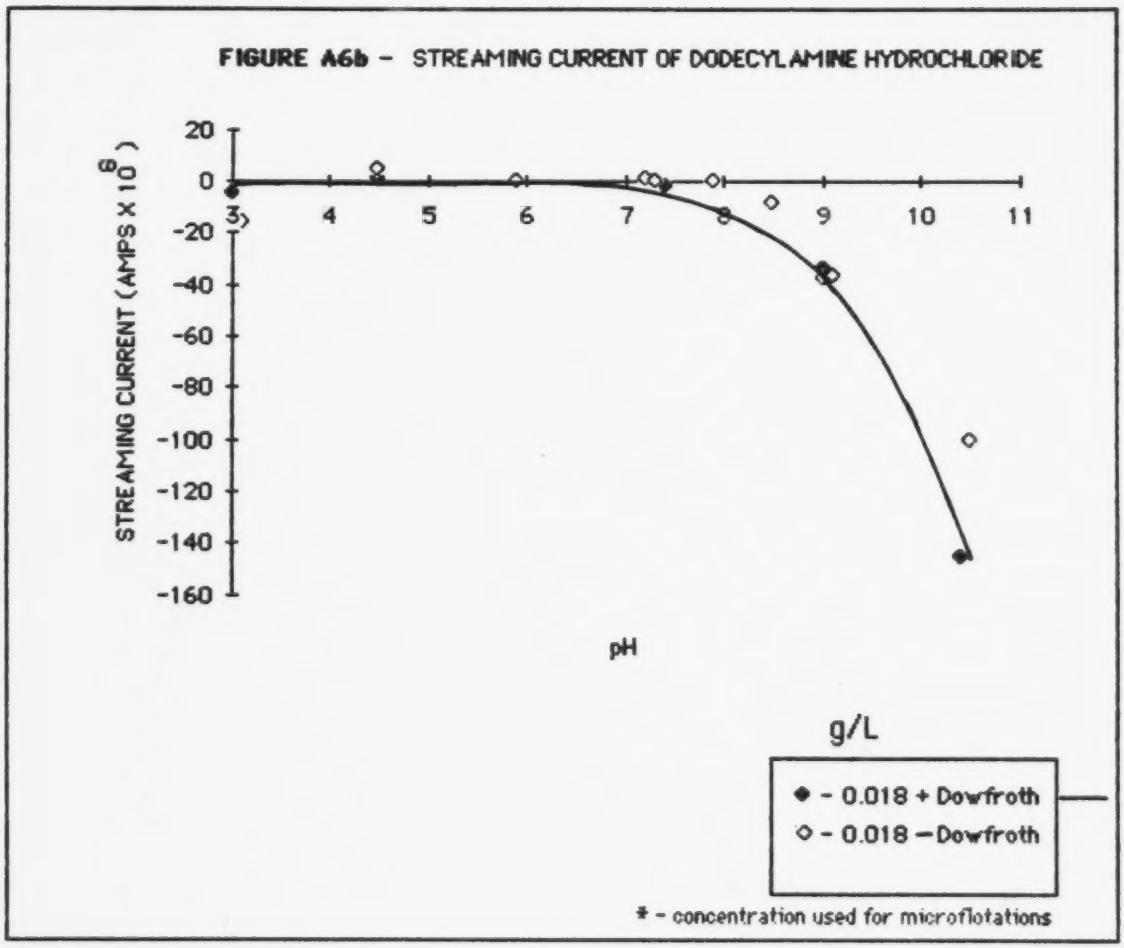
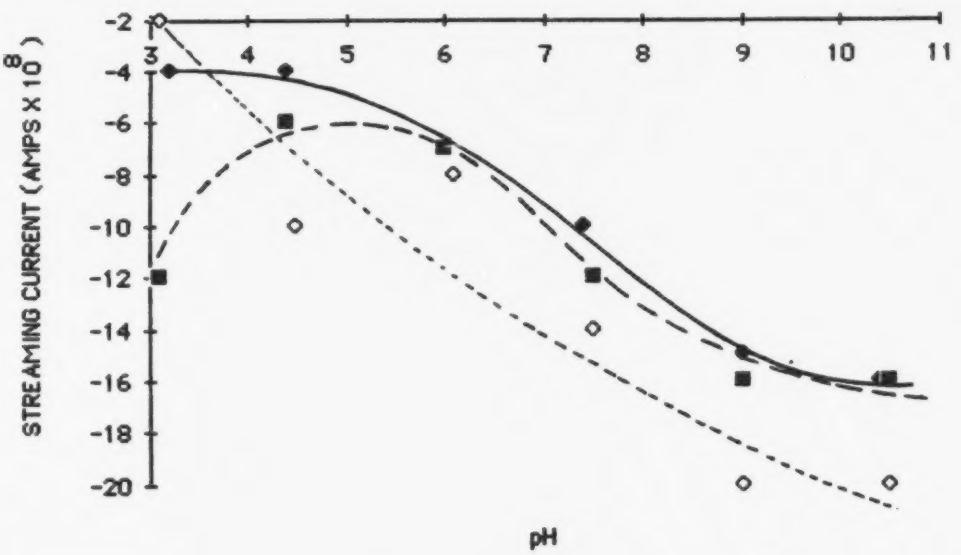


FIGURE A6b - STREAMING CURRENT OF DODECYLAMINE HYDROCHLORIDE
STREAMING CURRENT (AMPS X 10^6)
20
0
-20
-40
-60
-80
-100
-120
-140
-160
3
4
5
6
7
8
9
10
11
pH
g/L
◆ - 0.018 + Dowfroth
◇ - 0.018 - Dowfroth
* - concentration used for microflotations

FIGURE A7 – STREAMING CURRENT FOR STYRENE PHOSPHONIC ACID



g/L

◆ - 0.067 *

◇ - 0.133

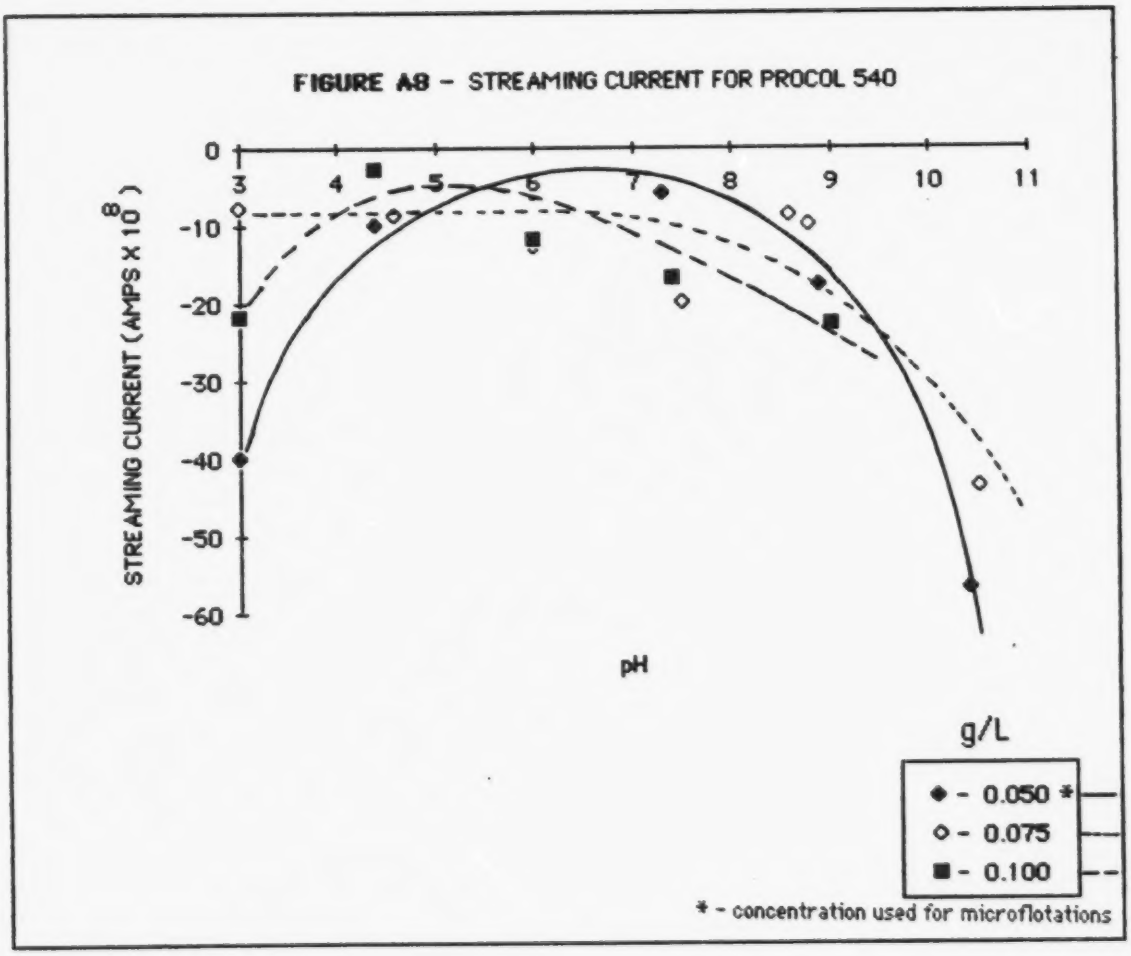
■ - 0.200

Styrene Phosphonic Acid

+ Dowfroth 250 at 0.013 g/l

* - concentration used for microflotations

FIGURE A8 – STREAMING CURRENT FOR PROCOL 540



APPENDIX B

ZETA POTENTIAL TESTWORK RESULTS

APPENDIX B - ZETA POTENTIAL

Figures B1-B8 show the zeta potential of quartz versus pH for each of the eight collectors tested, while figures B8-B16 show the zeta potential of cassiterite. These graphs do show scatter in the raw data however the smoothed curves for each of the three concentrations have a similar shape giving some confidence in the reliability of the data.

The raw data is presented in tabular form in APPENDIX D.

The conversion of the raw data to zeta potential is done using standard Helmholtz-Smoluchowski relationship.

$$Z.P. = \frac{4\pi n X Es}{D \quad dP}$$

where n = bulk viscosity

X = specific conductivity of solution in plug
= $\frac{C}{R}$ where C is a correction for cell geometry
R resistance of solution in plug

$$C = \frac{R \text{measured for known solution}}{R \text{actual for known solution}}$$

Es = streaming potential

D = dielectric constant

dP = applied pressure difference across the plug

For aqueous solutions at 25C and laminar flow through the plug the equation becomes:

$$Z.P. = 9.69 \times 10^4 \times \frac{C}{R} \times \frac{Es}{dP}$$

where C is the cell constant
R is in ohms
Es is in millivolts
dP is in centimeters of mercury
Z.P. is in millivolts

an example calculation is shown on the following page.

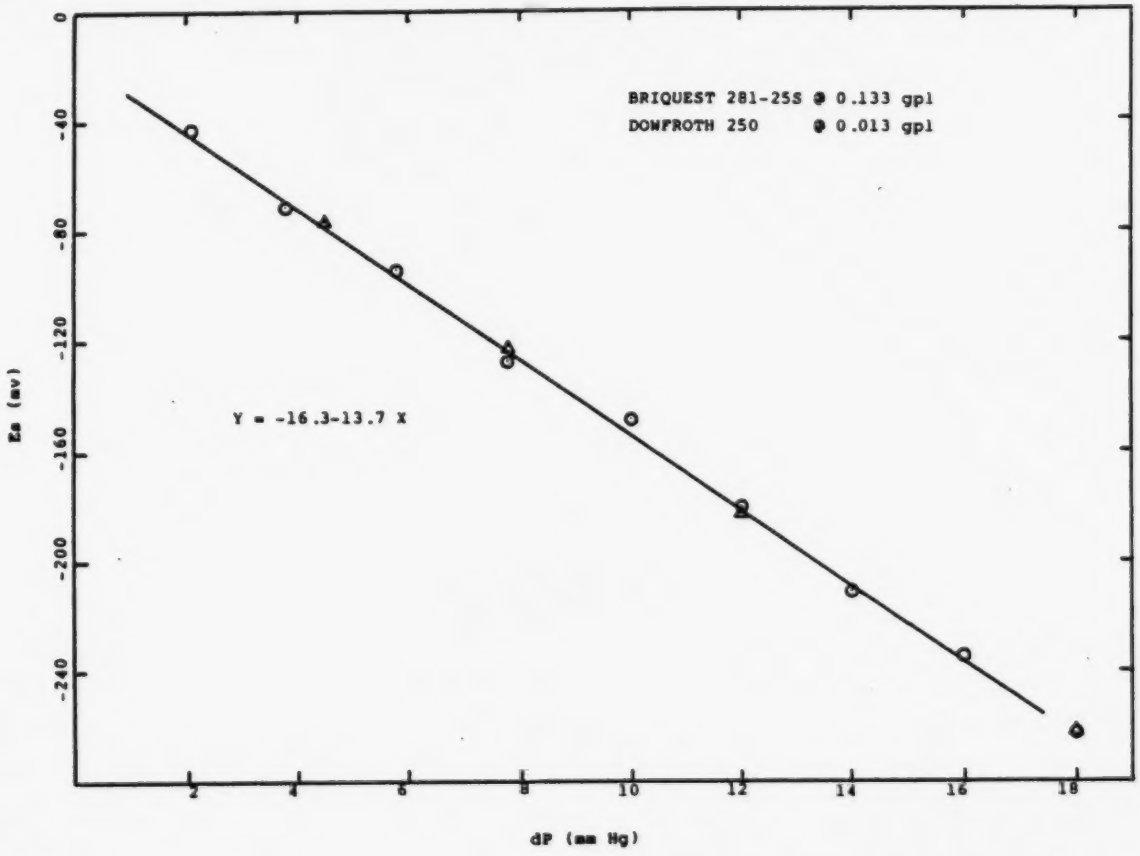
EXAMPLE ZETA POTENTIAL CALCULATION

Rmeas for KCl = 1598 ohms actual should be 77.7

therefore $C = \frac{Rmeas}{Ract} = \frac{1598}{77.8} = 20.54$

BRIQUEST 281-25S @ 0.133 g/L (~200 g/MT)
DOWFROTH 250 @ 0.013 g/L

pH = 9.0 T = 24 C R = 246,000 ohms



$$Z.P. = 9.69 \times 10^4 \times \frac{C \times Es}{R \quad dP}$$

$$Z.P. = 9.69 \times 10^4 \times \frac{20.54}{241000} \times \frac{-13.7}{}$$

$$= -113 \text{ mv}$$

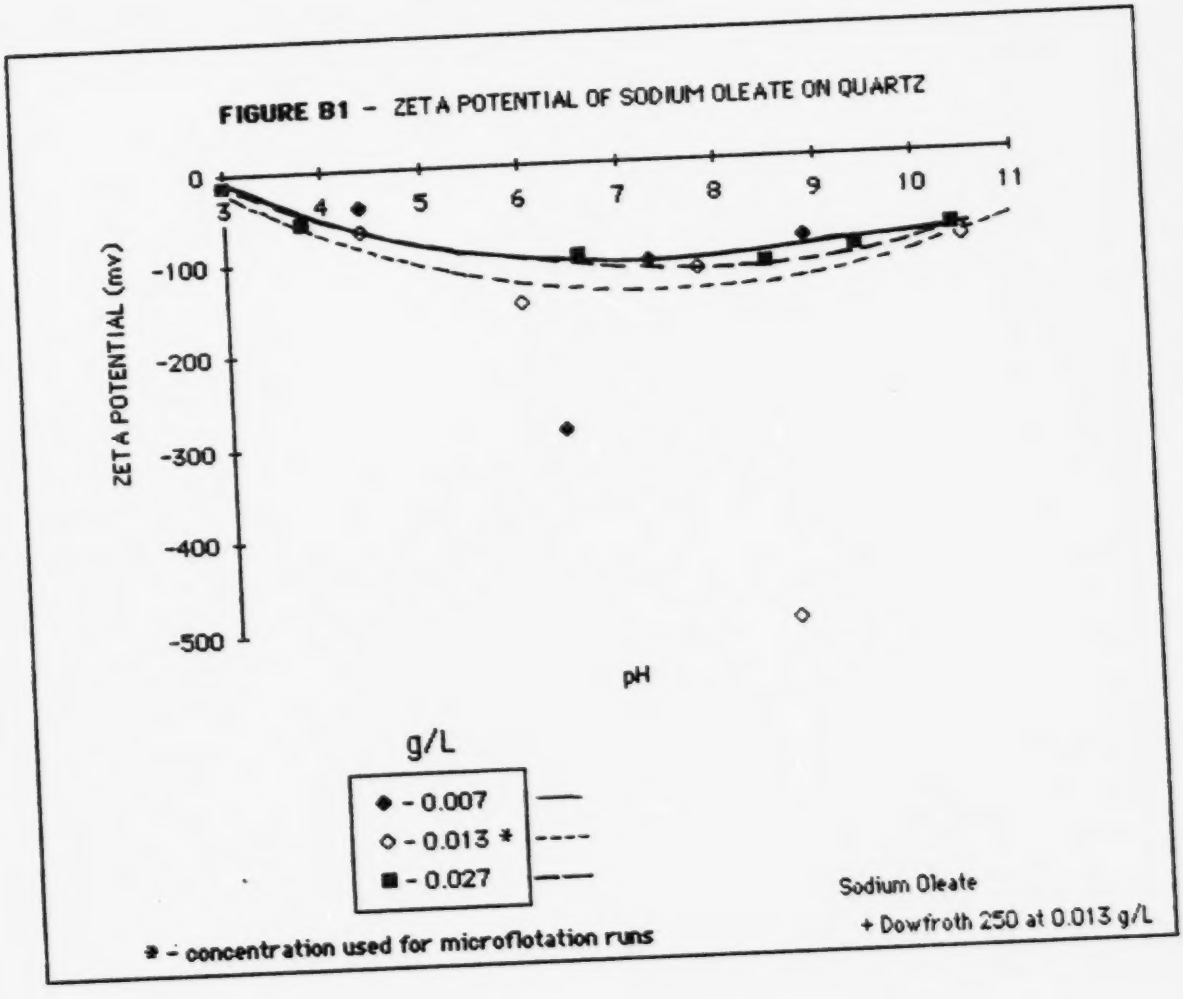
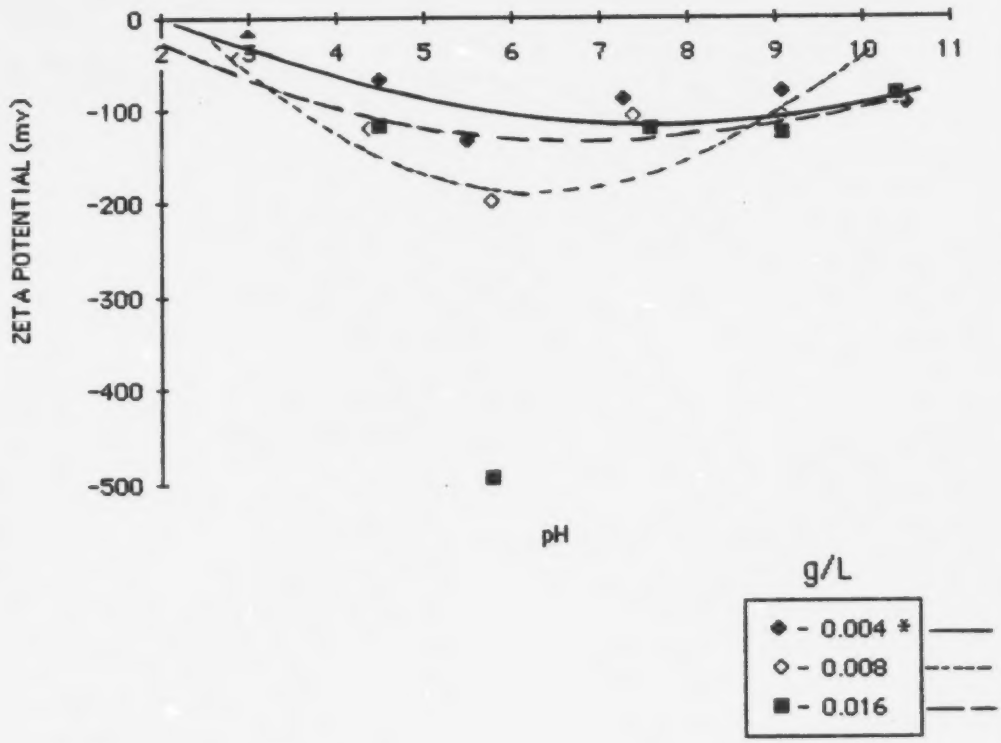


FIGURE B1 - ZETA POTENTIAL OF SODIUM OLEATE ON QUARTZ
0
-100
-200
-300
-400
-500
ZETA POTENTIAL (mv)
3
4
5
6
7
8
9
10
11
pH
g/L
◆ - 0.007
◇ - 0.013 *
■ - 0.027
* - concentration used for microflotation runs
Sodium Oleate
+ Dowfroth 250 at 0.013 g/L

FIGURE B2 – ZETA POTENTIAL OF SODIUM LAURYL SULPHATE ON QUARTZ



Sodium Laury1 Sulphate
+ Dowfroth 250 at 0.013 g/1

* – concentration used for microflotation runs

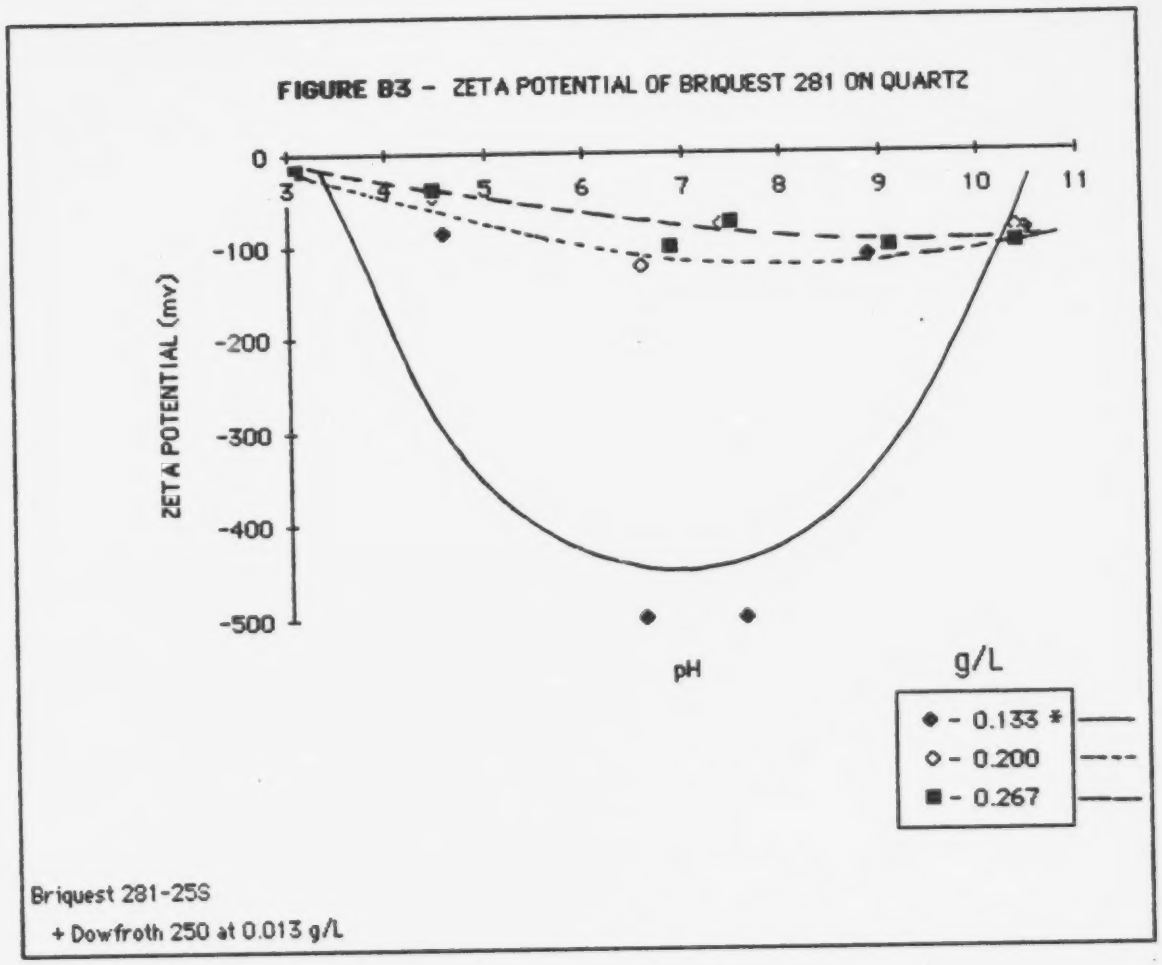
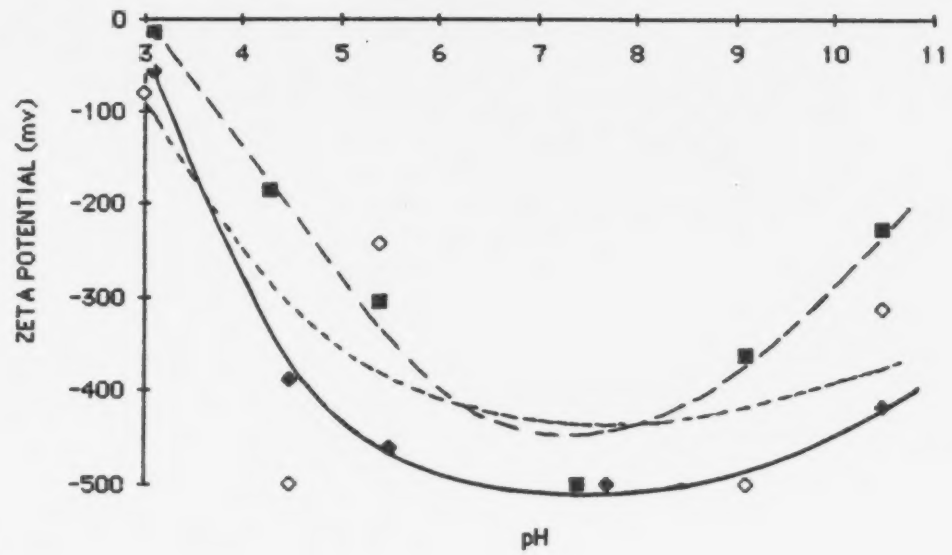


FIGURE B3 - ZETA POTENTIAL OF BRIQUEST 281 ON QUARTZ
0
-100
-200
-300
-400
-500
ZETA POTENTIAL (mv)
3
4
5
6
7
8
9
10
11
pH
g/L
◆ - 0.133 *
◇ - 0.200
■ - 0.267
Briquest 281-25S
+ Dowfroth 250 at 0.013 g/L

FIGURE B4 – ZETA POTENTIAL OF SALICYLALDEHYDE ON QUARTZ



g/L

◆ - 0.133 *

◇ - 0.200

■ - 0.267

Salicylaldehyde

+ Dowfroth 250 at 0.013 g/L

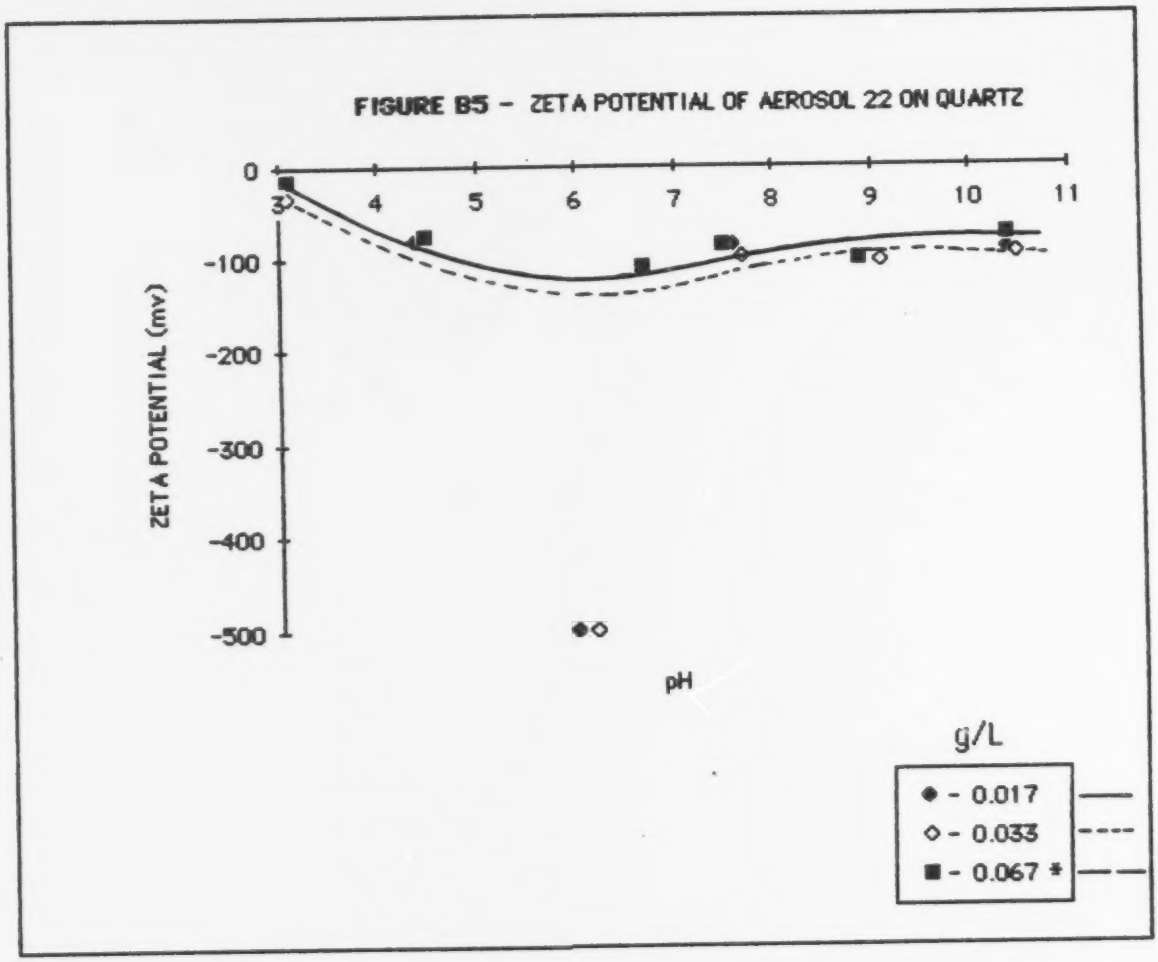
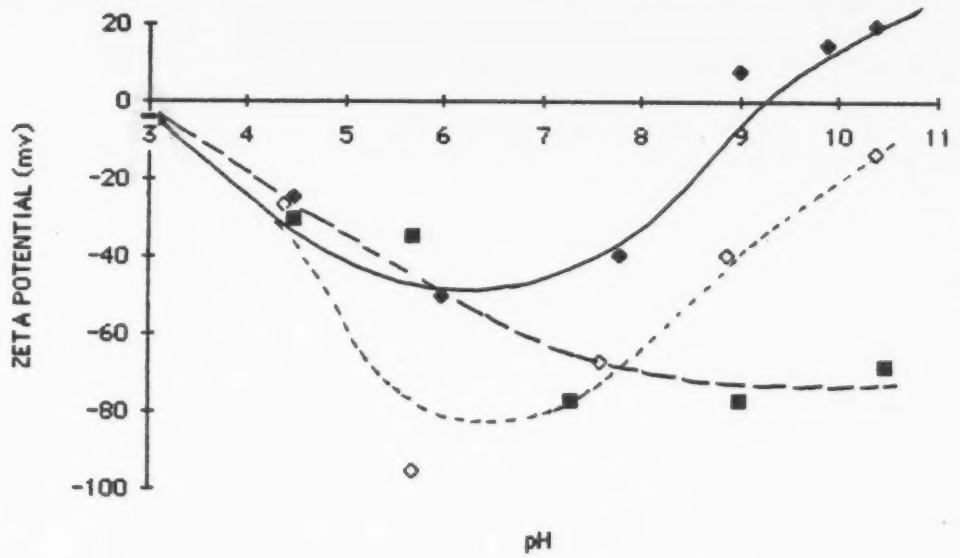


FIGURE B5 - ZETA POTENTIAL OF AEROSOL 22 ON QUARTZ
0
-100
-200
-300
-400
-500
ZETA POTENTIAL (mv)
3
4
5
6
7
8
9
10
11
pH
g/L
◆ - 0.017
◇ - 0.033
■ - 0.067 *

FIGURE B6 - ZETA POTENTIAL OF DODECYLAMINE HYDROCHLORIDE ON QUARTZ



g/L

■ - 0.001 * ——

◇ - 0.009 - - - - -

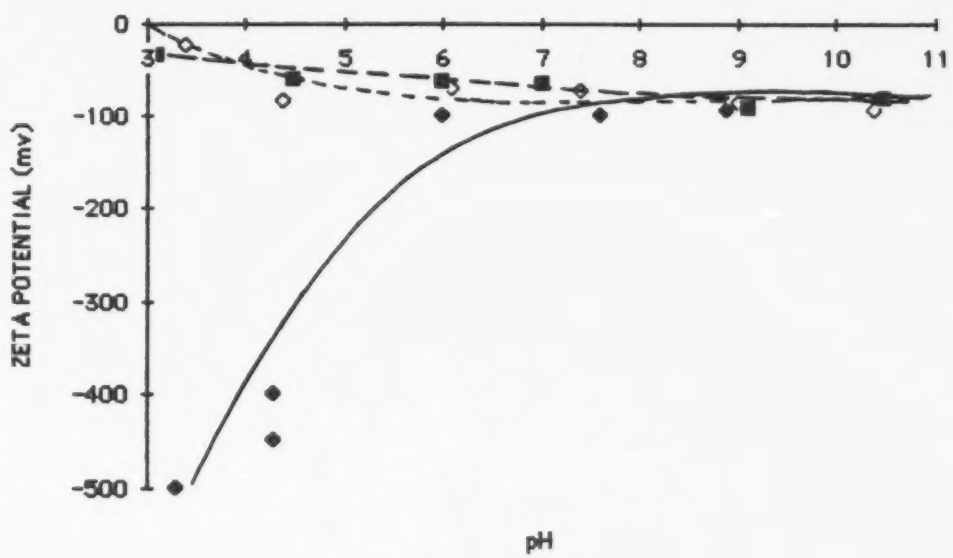
◆ - 0.018 — —

Dodecylamine Hydrochloride

+ Dowfroth 250 at 0.013 g/L

* - concentration used for the microflotations

FIGURE B7 – ZETA POTENTIAL OF STYRENE PHOSPHONIC ACID ON QUARTZ



Styrene Phosphonic Acid
+ Dowfroth 250 at 0.013 g/l

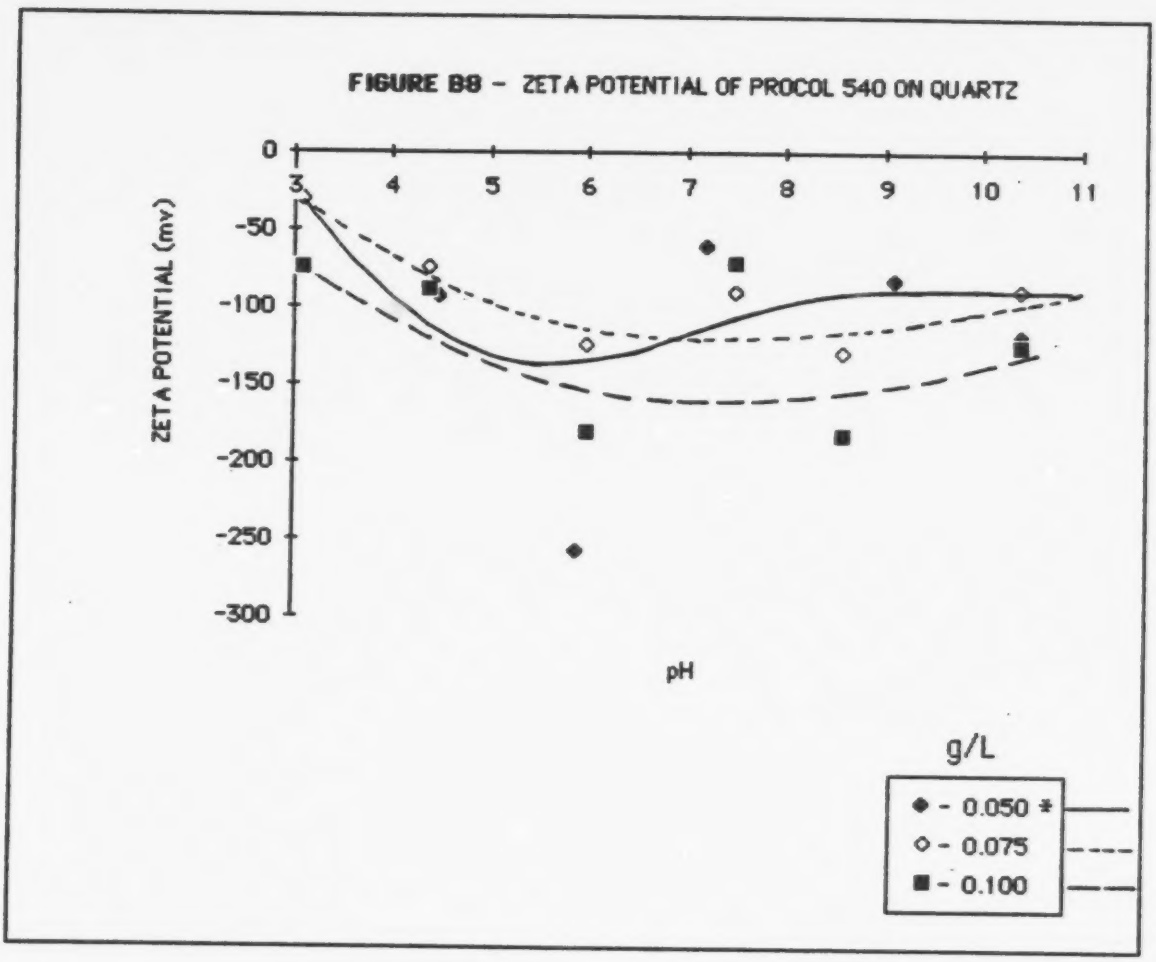


FIGURE B8 - ZETA POTENTIAL OF PROCOL 540 ON QUARTZ
ZETA POTENTIAL (mv)
0
-50
-100
-150
-200
-250
-300
3
4
5
6
7
8
9
10
11
pH
g/L
◆ - 0.050 *
◇ - 0.075
■ - 0.100

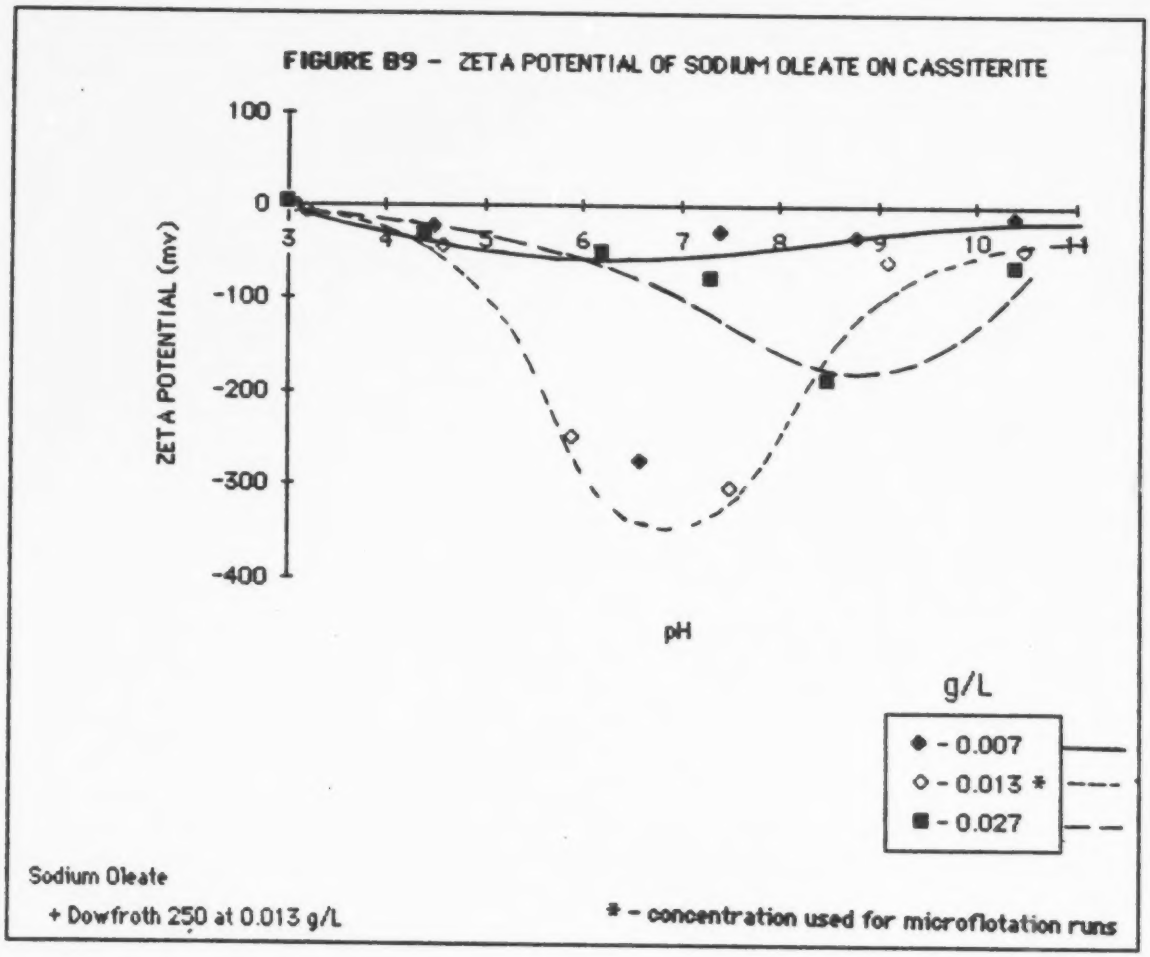


FIGURE B9 - ZETA POTENTIAL OF SODIUM OLEATE ON CASSITERITE
100
0
-100
-200
-300
-400
ZETA POTENTIAL (mv)
3
4
5
6
7
8
9
10
11
pH
g/L
◆ - 0.007
◇ - 0.013 *
■ - 0.027
Sodium Oleate
+ Dowfroth 250 at 0.013 g/L
* - concentration used for microflotation runs

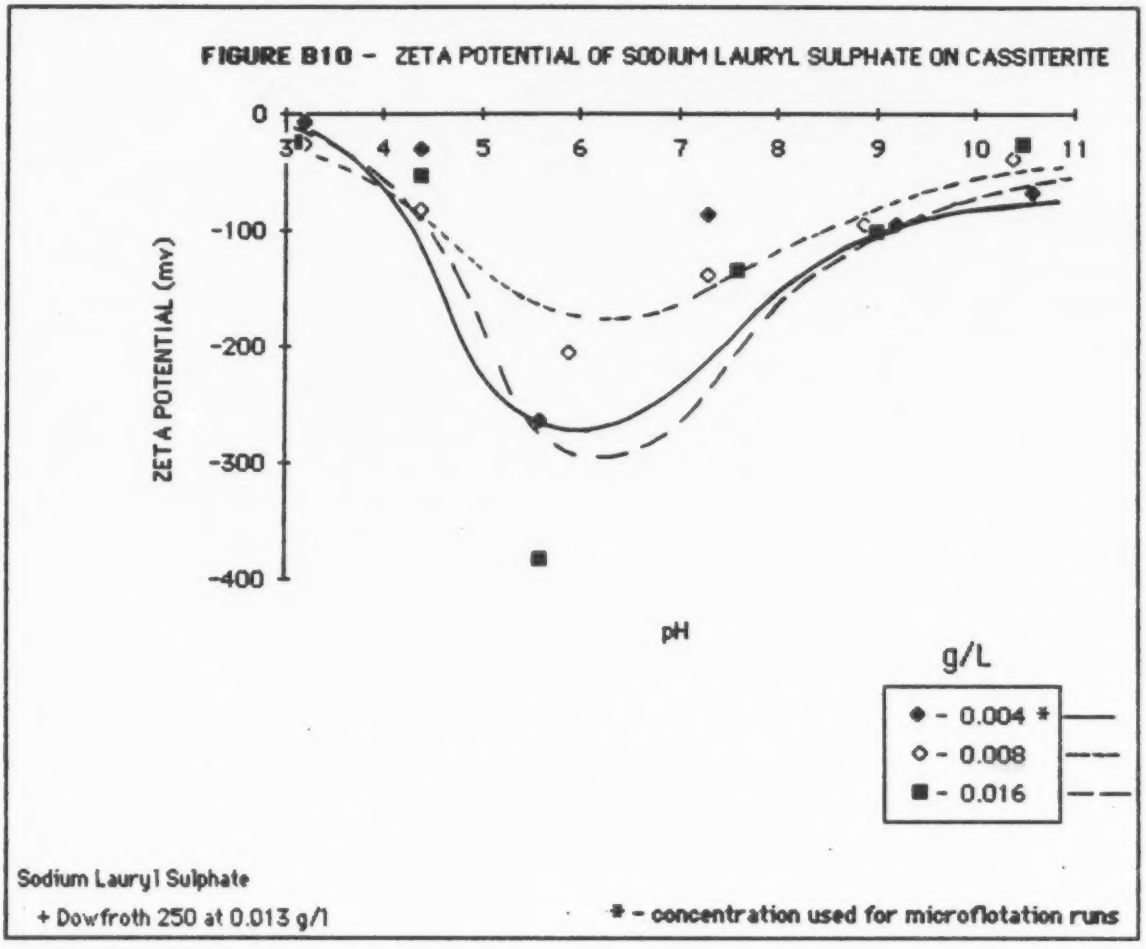
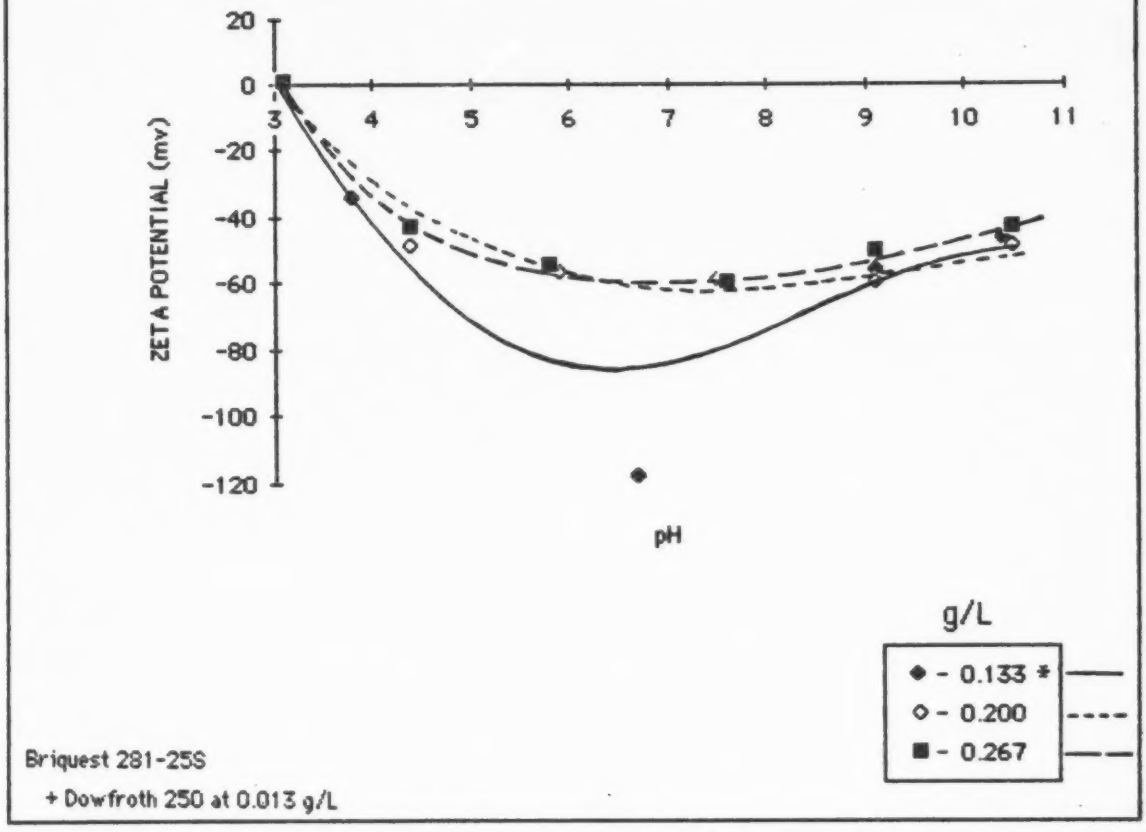


FIGURE B10 - ZETA POTENTIAL OF SODIUM LAURYL SULPHATE ON CASSITERITE
0
-100
-200
-300
-400
3
4
5
6
7
8
9
10
11
ZETA POTENTIAL (mv)
pH
g/L
◆ - 0.004 *
◇ - 0.008
■ - 0.016
Sodium Lauryl Sulphate
+ Dowfroth 250 at 0.013 g/l
* - concentration used for microflotation runs

FIGURE B11 - ZETA POTENTIAL OF BRIQUEST 281 ON CASSITERITE



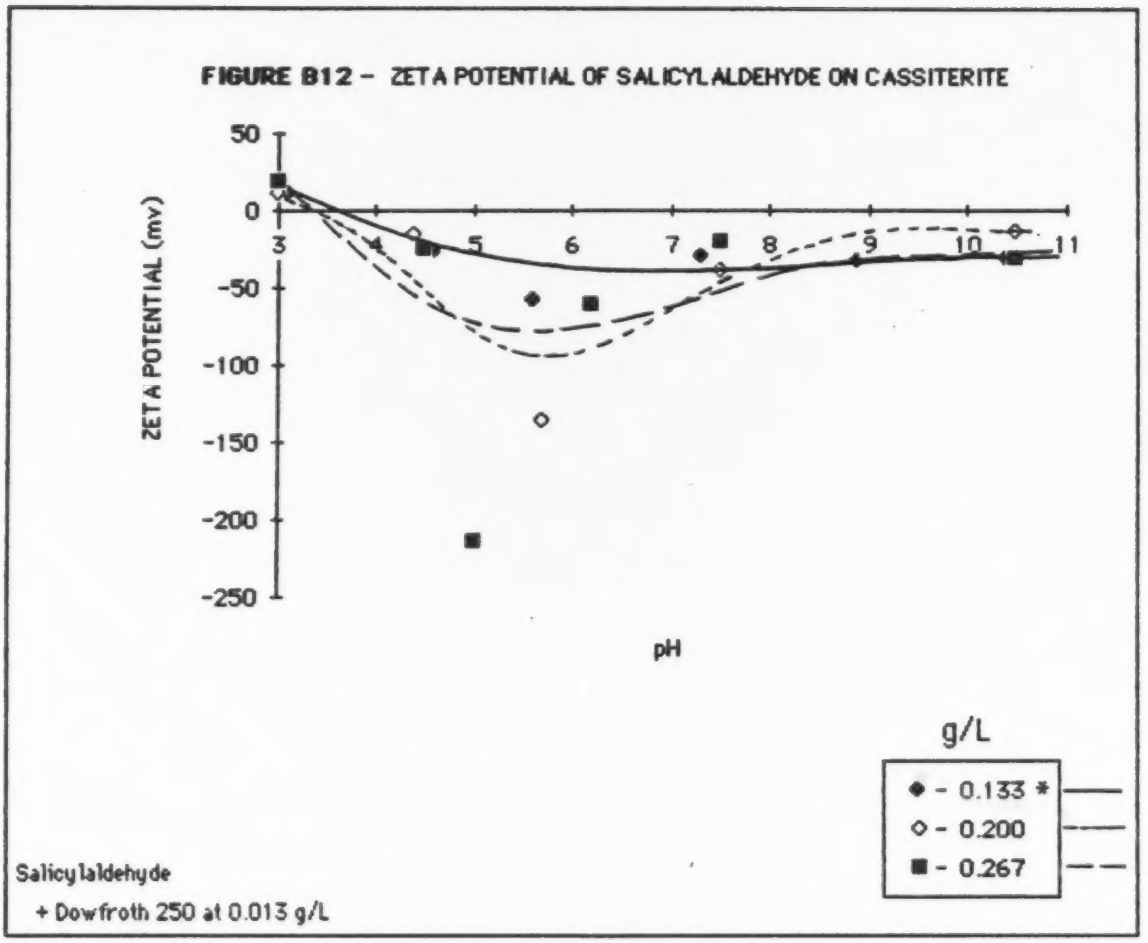


FIGURE B12 - ZETA POTENTIAL OF SALICYLALDEHYDE ON CASSITERITE
ZETA POTENTIAL (mv)
50
0
-50
-100
-150
-200
-250
3
4
5
6
7
8
9
10
11
pH
g/L
◆ - 0.133 *
◇ - 0.200
■ - 0.267
Salicylaldehyde
+ Dowfroth 250 at 0.013 g/L

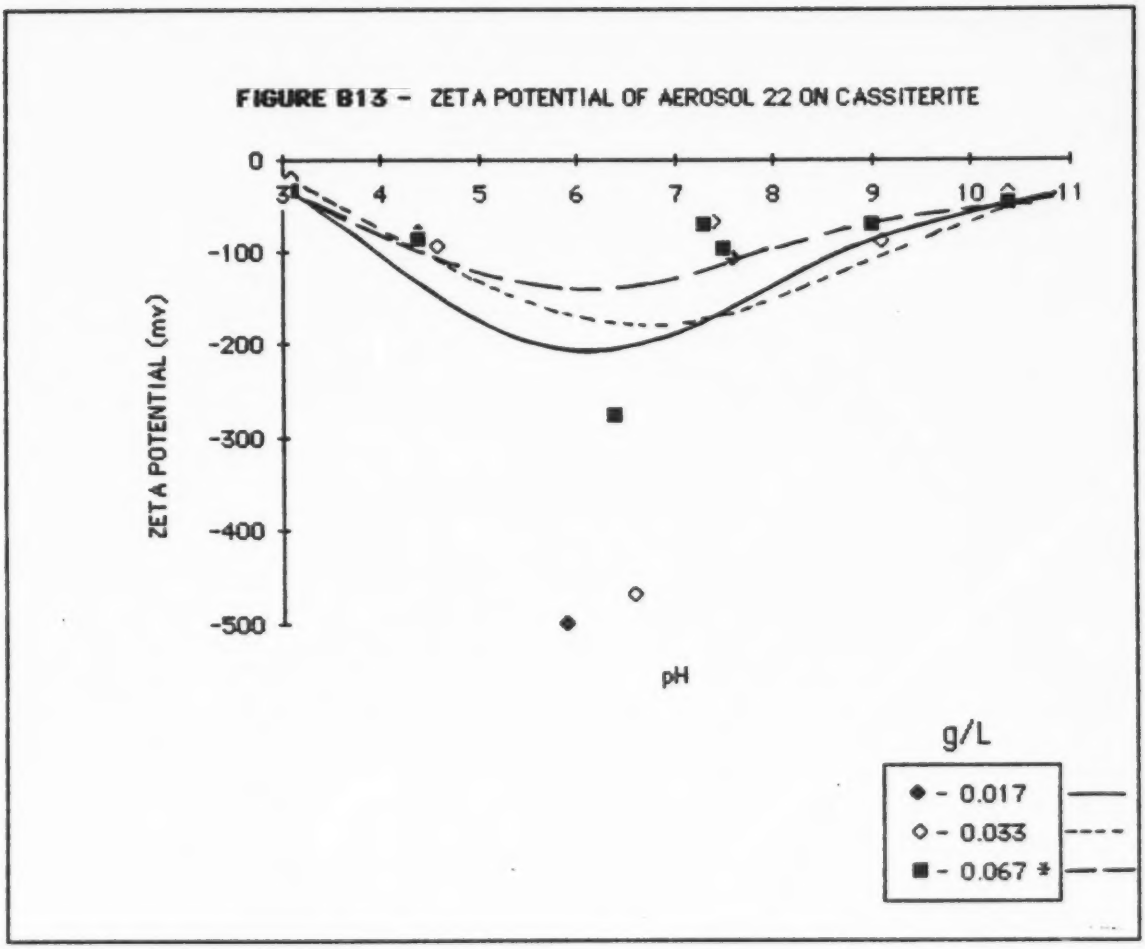
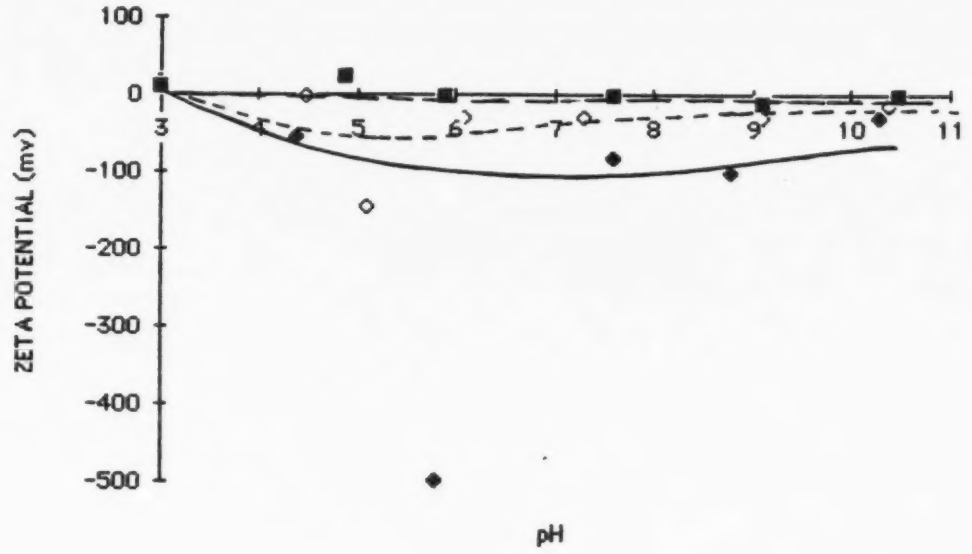


FIGURE B13 - ZETA POTENTIAL OF AEROSOL 22 ON CASSITERITE
0
-100
-200
-300
-400
-500
ZETA POTENTIAL (mv)
3
4
5
6
7
8
9
10
11
pH
g/L
◆ - 0.017
◇ - 0.033
■ - 0.067 *

FIGURE B14 - ZETA POTENTIAL OF DODECYLAMINE HYDROCHLORIDE ON CASSITERITE



g/L

◆ - 0.001 *

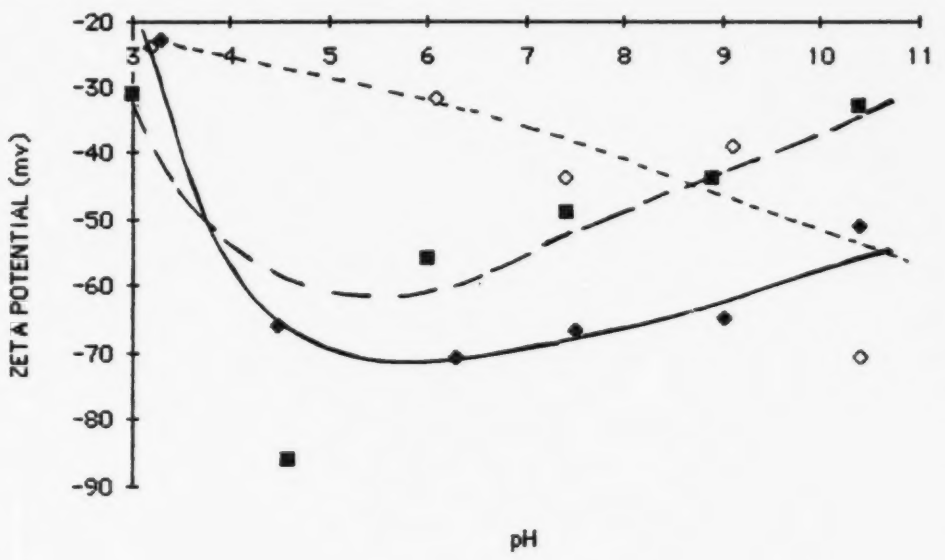
◇ - 0.009

■ - 0.018

Dodecylamine Hydrochloride

+ Dowfroth 250 at 0.013 g/L

FIGURE B15 – ZETA POTENTIAL OF STYRENE PHOSPHONIC ACID ON CASSITERITE



g/L

◆ - 0.067 *

◇ - 0.133

■ - 0.200

Styrene Phosphonic Acid

+ Dowfroth 250 at 0.013 g/l

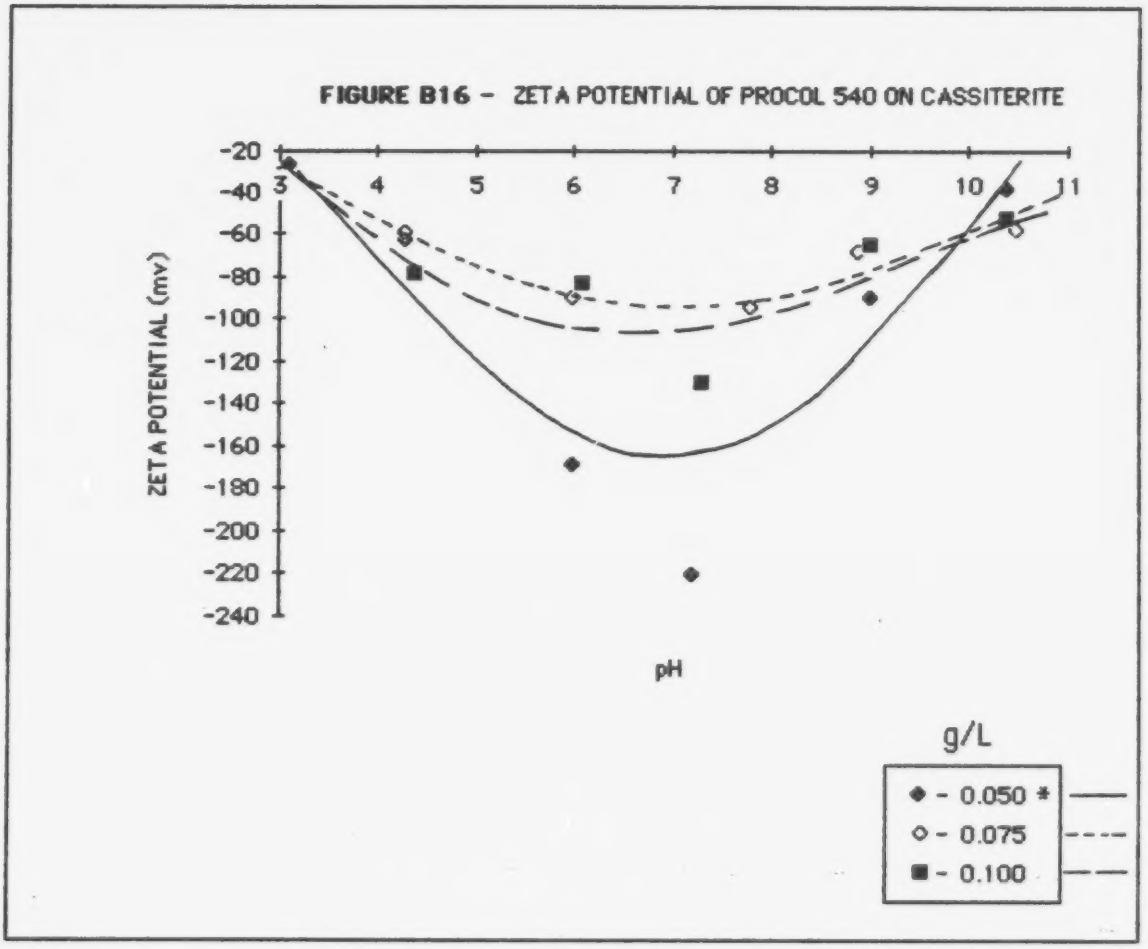


FIGURE B16 - ZETA POTENTIAL OF PROCOL 540 ON CASSITERITE
ZETA POTENTIAL (mv)
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
3
4
5
6
7
8
9
10
11
pH
g/L
◆ - 0.050 *
◇ - 0.075
■ - 0.100

APPENDIX C

SIZE ANALYSIS AND ASSAYS OF QUARTZ AND CASSITERITE

APPENDIX C

Preparation and Size Analysis of Quartz Fractions

The quartz used in this study was from a sample of silica sand which had been leached in aqua regia for 48 hours. This material was then ground in a ceramic ball mill for 30 minutes, filtered and dried. The -65 +100 mesh quartz used in the Zeta cell was prepared by dry screening. Wet screening at 325 and 400 mesh was used to produce the coarse size fraction -44 +37 microns used in flotation. The -400 mesh quartz was ground for a further 4.5 hours in the ceramic mill to produce the smaller size fractions which were classified using settling techniques into the -10 +5 micron fraction and the -5 micron fraction. A sample of the quartz submitted for analysis had the following assay:

Quartz Semi-quantitative Analysis

	(PPM)		(PPM)		(%)
Ba	100.	Mg	200.	Fe	0.1
Cd	3.	Mn	10.	K	0.3*
Ca	200.	Ni	3.	Ag	0.3
Cr	5.	Sr	10.	Na	0.2*
Cu	100.	Sn	100.	Al	1.0
Ga	7.	Ti	500.*		
Pb	100.	V	10.		
Zn	200.*				

* estimates are very rough

The results of the size analysis of the two -10 um fractions are shown in Fig. C1 and C2.

Analysis of the -10 +5 um data show a d_{50} = 11.5 microns on a weight basis or a d_{50} = 6.9 microns on a population basis.

Analysis of the -5 um data show a d_{50} = 5.4 microns on a weight basis or a d_{50} = 4.2 microns on a population basis.

A sample of the -10 +5 um quartz was submitted for SEM analysis. Photo's taken randomly of the powder showed angular particles in the size range 3 to 25 um. EDX spot analyses gave with very few exceptions Si, representing SiO_2. Among the impurities Sn,Zn,S,Fe,Al, and Cu were found as illustrated in Fig C3-C4.

Preparation and Size Analysis of Cassiterite Fractions

A sample of tin concentrate was obtained from Cominco's Sullivan mine in Kimberley BC. The concentrate was leached for 3 hours at 70C in 2M $FeCl_3$ saturated with NaCl then filtered, washed and dried. Dry screening this material produced negligible quantities of -65 +100M cassiterite for use in the Zeta cell, therefore the fraction -150 +200M was used. The coarse size fraction used in flotation was prepared by wet screening at 325 and 400 mesh to produce a sample -44 +37 microns.

The -400 mesh material was ground in a rubber lined ball mill for 13.5 hours and classified using settling techniques into the -10 +5 micron and the -5 micron fractions. After each stage of grinding the material was put through a Franz Isodynamic separator to remove any iron produced by the grinding media. Then individual size fractions were again leached this time for 4 hours at 50C in 2M $FeCl_3$ saturated with NaCl, filtered, washed, and dryed. A portion of the -325 + 400M and -10 +5 micron fractions were combined and assayed. Classical analysis of this sample indicated the feed was 76.4% Sn or 97% cassiterite and 0.5% total iron.

Cassiterite Semi-quantitative Analysis

	(%)		(%)		(%)		(%)
Ca	.1	Mn	.02	Zn	.2	Cs	.00005
Al	.03	Li	.01	W	~1.0	Ge	.0002
As	.03	Pb	.03	Ag	.00005	Co	.00007
Ba	.005	Si	.5	Sr	.0007	Cu	.0005
Be	.002	Sb	.002	Bi	.00001	Y	.001
Ti	.2	Ni	.002	Mo	.0002	Yb	.005
B	.0002	Cr	.007				

The results of the size analysis of the two -10 um fractions are shown in Fig. C6 and C7.

Analysis of the -10 +5 um fraction shows a d_{50} = 6.1 microns on a weight basis or a d_{50} = 4.3 microns on a population basis.

Analysis of the -5 um fraction shows a d_{50} = 4.7 microns on a weight basis or a d_{50} = 2.4 microns on a population basis.

A sample of the -10 +5 um cassiterite was submitted for SEM analysis. Photos taken randomly of the powder showed angular particles often with subconchoidal surfaces in the size range 1 to 15 um. EDX spot analyses tentativley identified Zircon $ZrSiO_4$ as well as Fe,W,Zn,Cu, and Cr as illustrated in Fig C7-C9.

FIGURE C1 - COULTER COUNTER ANALYSIS OF -10 + 5 µm QUARTZ

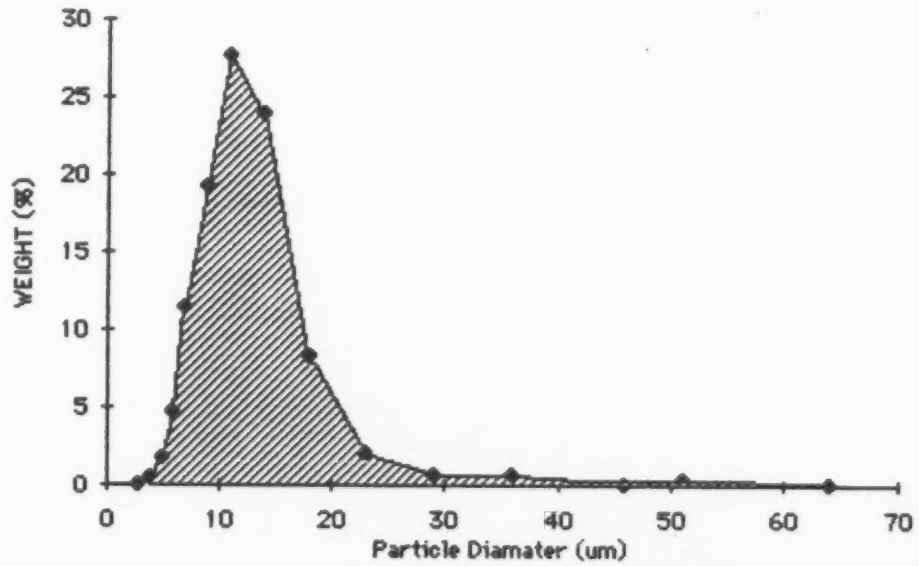


FIGURE C2 – COULTER COUNTER ANALYSIS OF -5 µm QUARTZ

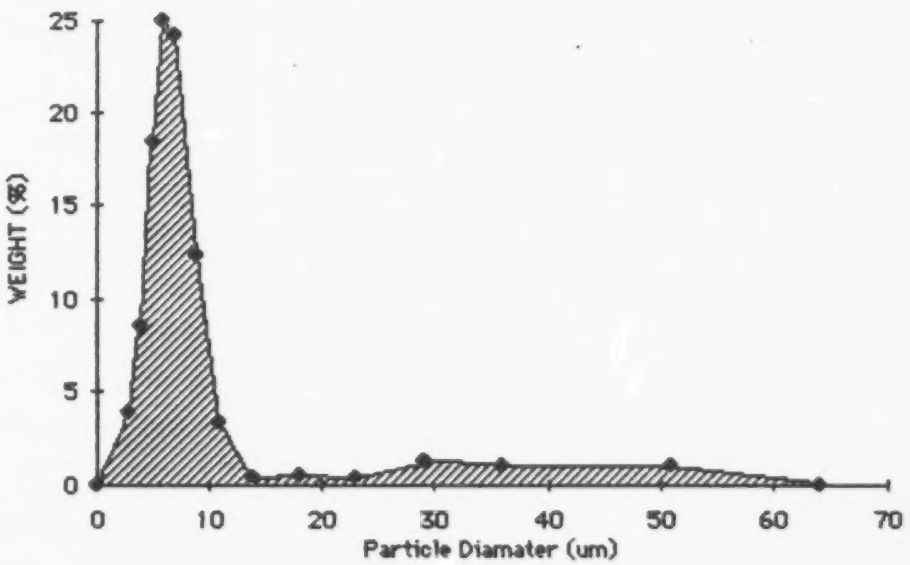
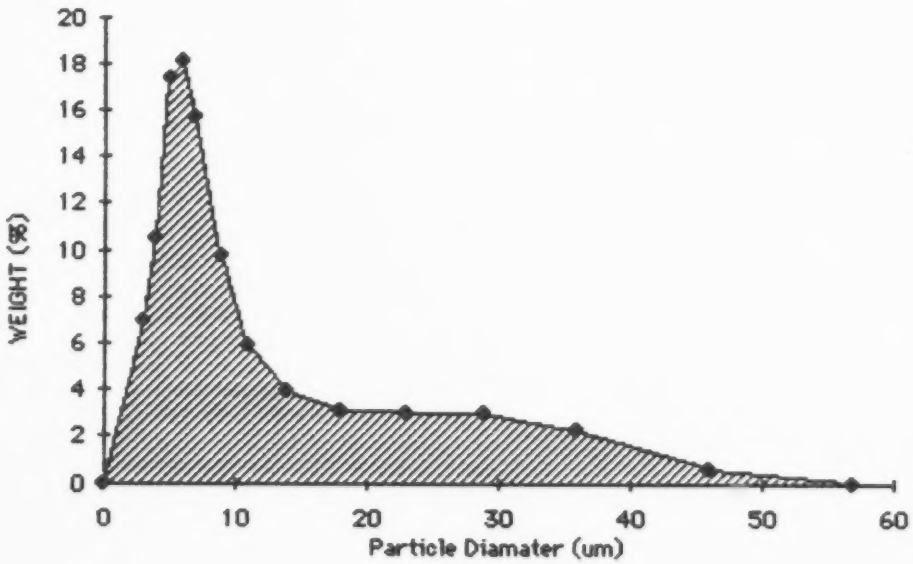


FIGURE C3 - SEM PHOTOGRAPH OF -10 +5 um QUARTZ

FIGURE C4 - SEM PHOTOGRAPH OF -10 +5 um QUARTZ

Fig. 1b

FIGURE C5 - COULTER COUNTER SIZE ANALYSIS OF -10 +5 um Cassiterite



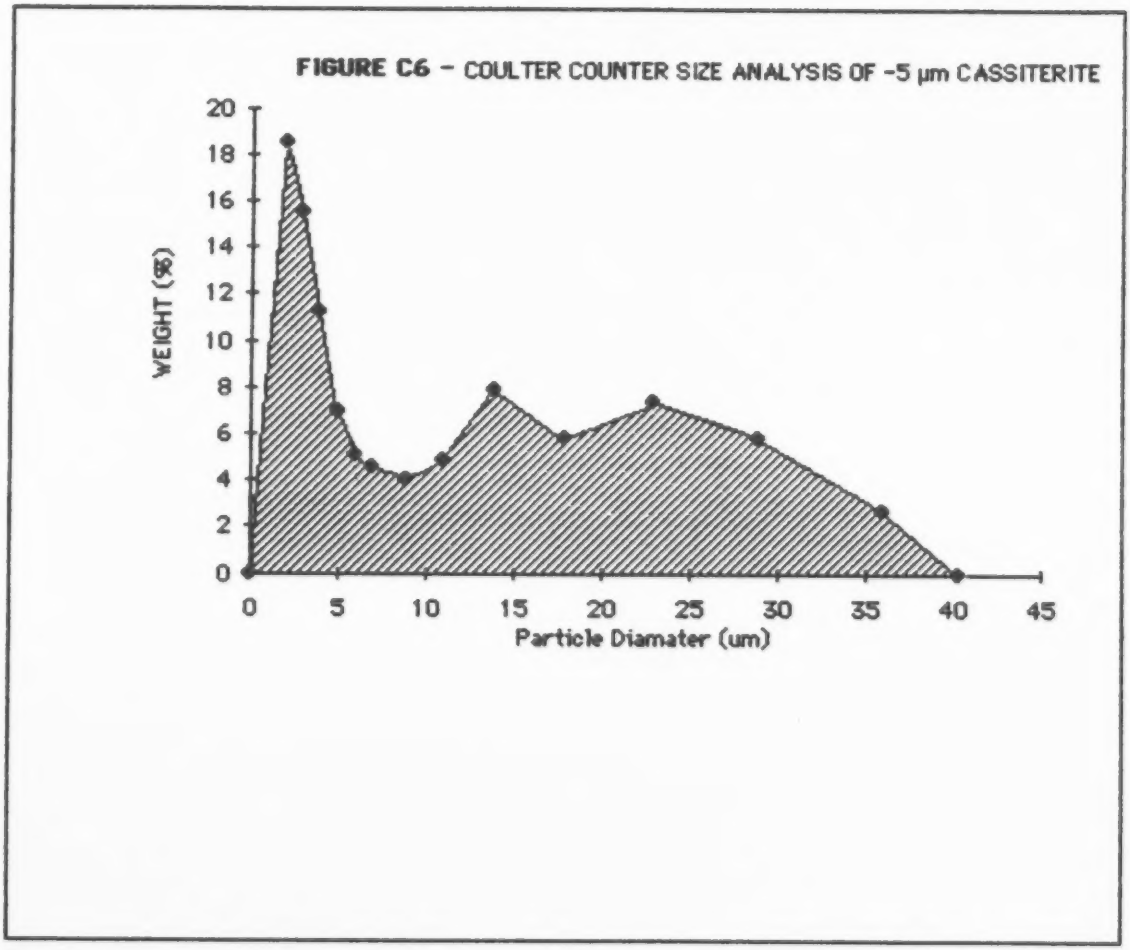


FIGURE C6 – COULTER COUNTER SIZE ANALYSIS OF -5 µm CASSITERITE

FIGURE C7 - SEM PHOTOGRAPH OF -10 +5 µm CASSITERITE

Fig.1

CASSITERITE

SIZE :-10+5 µm
PARTICLES
AS - RECEIVED
2000X,BSE

1 mm ~ .5 µm

Examples for:

SnO_2 = •
Fe-Sn+ = O
$ZrSiO_4$ = ●

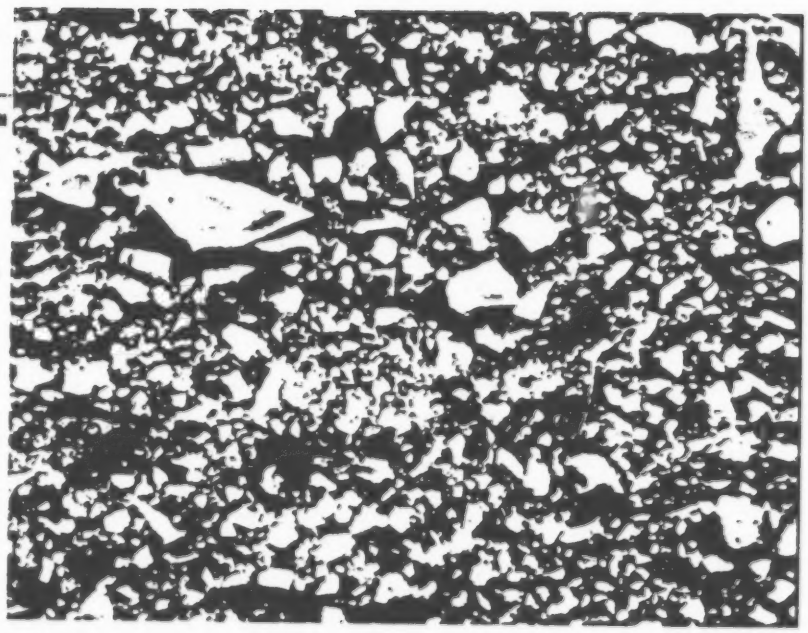


FIGURE C8 - SEM PHOTOGRAPH OF -10 +5 um CASSITERITE

Fig. 2

CASSITERITE

SIZE :-10+5 µm
PARTICLES
AS - RECEIVED
2000X, BSE

1 mm = .5 µm

Examples for:

SnO_2 = •
Fe-Sn+ = O
$ZrSiO_4$ = ▪

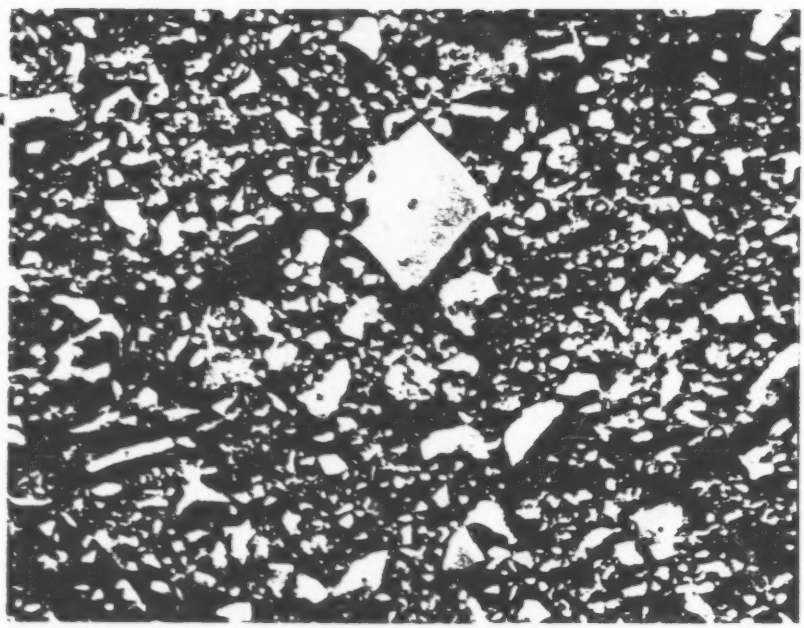
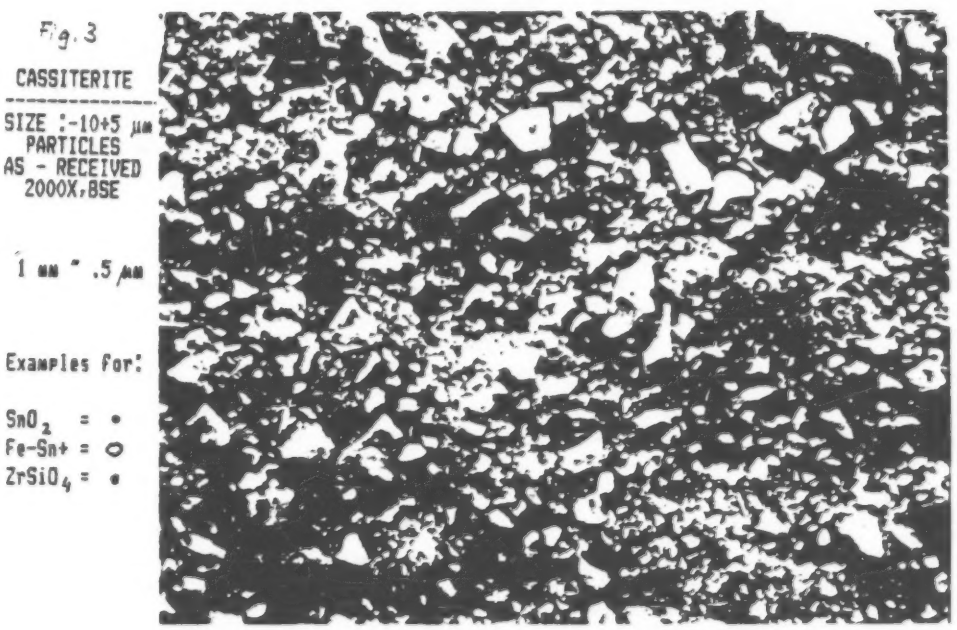


FIGURE C9 - SEM PHOTOGRAPH OF -10 +5 um CASSITERITE



APPENDIX D

TESTWORK TABULAR RESULTS

STREAMING CURRENT RAW TEST RESULTS

On the following pages the raw data measured in the tests is presented in tabular form. This data is presented graphically in Figures A1-A8.

The following abbreviations were used:

ss	reading slow to stabilize
ns	reading not stable
nf	no froth
sf	some(light) froth
hf	heavy froth
scum	scum layer formed on surface
check	cell shorted and reading repeated
repeat	measurement repeated on subsequent run
yellow	the solution had a yellow colour

1a)Streaming Current of Sodium Oleate @ 0.007 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	5380	108	-0.025	-23	
4.0	69500	1389	-0.062	-4	
6.4	525000	10508	-0.370	-4	ss
6.5	530000	10608	-0.320	-4	check
6.5	565000	11117	-0.038	0	repeat
7.3	250000	5004	-0.150	-3	repeat
7.4	390000	7804	-0.200	-3	repeat
7.5	213000	4263	-0.450	-11	
8.9	132000	2639	-0.500	-19	repeat
9.0	192000	3840	-0.330	-9	repeat
9.0	120000	2400	-0.490	-20	repeat
9.0	82100	1642	-0.460	-28	
10.4	6650	133	-0.082	-62	
10.4	19200	383	-0.300	-78	repeat
10.5	15600	312	-0.200	-64	repeat

1b)Streaming Current of Sodium Oleate @ 0.013 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.1	4240	85	-0.020	-24	
4.5	81000	1619	-0.068	-4	repeat
4.5	67500	1349	-0.062	-5	
5.9	87000	1741	-0.340	-20	
7.4	300000	6004	-0.290	-5	repeat
7.5	426000	8526	-0.750	-9	
7.6	436000	8725	-0.740	-8	repeat
8.9	126000	2522	0.040	2	
8.9	157000	3141	-0.480	-15	repeat,ss
9.0	150000	3002	-0.850	-28	repeat
10.3	6900	138	-0.022	-16	hf
10.5	13300	266	-0.140	-53	repeat,hf

1c)Streaming Current of Sodium Oleate @ 0.027 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	3850	78	-0.019	-24	
4.3	50000	1001	-0.044	-4	
4.5	59200	1184	-0.058	-5	repeat
5.9	73500	1469	-0.380	-26	
7.9	204000	4083	-0.060	-1	
8.0	221000	4442	-0.630	-14	repeat
8.5	148000	2959	-0.400	-14	repeat
8.8	110000	2200	-0.400	-18	repeat,ss
9.0	83000	1659	0.110	7	ss
10.4	5000	100	-0.010	-10	ss,hf

2a)Streaming Current of Sodium Lauryl Sulphate @ 0.004 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.1	2550	51	-0.024	-47	
4.4	172100	3441	-0.002	0	
5.2	730000	11100	-0.140	-1	check
5.3	750000	11100	-0.120	-1	
7.3	114500	2290	-0.100	-4	
9.0	62000	1239	-0.150	-12	
10.4	7000	140	-0.089	-64	

2b)Streaming Current of Sodium Lauryl Sulphate @ 0.008 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.1	2890	58	-0.013	-22	
4.6	160000	3202	-0.200	-6	hf
5.7	122500	2451	-0.038	-2	
7.4	79000	1579	-0.039	-2	hf
9.0	49200	983	-0.019	-2	hf,ss
10.5	4050	81	-0.031	-38	

2c)Streaming Current of Sodium Lauryl Sulphate @ 0.016 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	4500	90	-0.018	-20	
4.5	144000	2879	-0.003	0	
5.4	261000	5223	-0.060	-1	hf
7.5	120000	2400	-0.035	-1	
9.0	62000	1239	-0.065	-5	
10.6	4220	85	-0.070	-82	

3a)Streaming Current of Briquest 281-25S @ 0.133 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.1	3755	75	-0.017	-23	sf
4.5	32900	657	-0.029	-4	sf
6.3	42500	850	-0.015	-2	check,ss
6.5	44500	891	-0.020	-2	sf
7.1	32100	641	-0.030	-5	sf
9.0	23300	466	-0.035	-8	sf
10.4	3100	62	-0.030	-48	sf
10.6	3490	77	-0.018	-23	check,ns

3b)Streaming Current of Briquest 281-25S @ 0.200 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	3000	60	-0.027	-45	sf
4.5	26000	520	-0.039	-8	sf
6.4	30000	600	-0.045	-8	sf
6.4	29500	589	-0.046	-8	check,sf
7.5	19600	392	-0.046	-12	sf
9.0	4550	91	-0.032	-35	sf
10.5	3875	78	-0.036	-46	sf

3c)Streaming Current of Briquest 281-25S @ 0.267 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	2860	57	-0.013	-23	sf
4.5	1840	37	0.002	5	sf
6.5	23000	459	-0.055	-12	sf
7.4	15400	307	-0.039	-13	sf
9.0	10200	204	-0.022	-11	sf
10.4	3050	61	-0.030	-49	sf

4a)Streaming Current of Salicylaldehyde @ 0.133 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	2330	47	-0.028	-60	sf
4.4	83000	1659	-0.025	-2	sf
5.4	1107000	11117	0.002	0	sf
7.4	43500	869	-0.110	-13	sf,yellow
9.1	10800	216	-0.020	-9	sf,yellow
10.5	2660	54	-0.015	-28	sf,yellow
10.5	9200	184	0.150	82	repeat,ss,sf

4b)Streaming Current of Salicylaldehyde @ 0.200 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	2940	59	-0.028	-47	sf
4.5	122000	2440	-0.023	-1	sf
5.4	1102000	11120	0.008	0	sf
7.4	69000	1380	-0.048	-3	sf,yellow
9.1	8500	170	-0.017	-10	sf,yellow
10.1	7200	144	0.027	19	ss
10.5	2770	56	0.015	27	sf,yellow
10.5	3900	78			repeat,ns

4c)Streaming Current of Salicylaldehyde @ 0.267 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	4300	86	-0.023	-27	sf
4.9	820000	11100	0.025	0	sf
5.9	220000	4402	-0.060	-1	sf,yellow
7.5	30500	609	-0.023	-4	sf,ss,yellow
8.9	8900	178	-0.011	-6	sf,ns
10.5	3840	77	-0.010	-13	sf

Comments - yellow - solution changed from clear to bright yellow color.

5a)Streaming Current of Aerosol 22 @ 0.017 g/L - No Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	3320	67			ns,hf
4.4	102000	2041	-0.050	-2	sf
6.1	350000	7011	-0.027	0	ns,sf
7.4	87600	1751	-0.054	-3	ss,sf
9.1	38100	761	-0.057	-7	ss,sf
10.3	15000	301	-0.036	-12	sf

5b)Streaming Current of Aerosol 22 @ 0.033 g/L - No Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	4250				ns,hf
4.5	60500	1210	-0.064	-5	ss,sf
6.2	211000	4223	-0.150	-4	sf
7.4	64200	1285	-0.053	-4	sf
9.0	49400	987	-0.063	-6	sf
10.4	6000	121	-0.013	-11	sf

5c)Streaming Current of Aerosol 22 @ 0.067 g/L - No Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0					ns,hf
4.6	57200				ns,hf
6.1	105000	2100	-0.006	0	sf
7.3	52000	1040	-0.100	-10	ss,sf
9.0	22600	453	-0.059	-13	sf
10.4	11900	239	-0.073	-31	sf

5d)Streaming Current of Aerosol 22 @ 0.133 g/L - No Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0					ns,hf
4.5					ns,hf
6.6	59200	1185	-0.079	-7	ss,sf
7.4	55100	1103	-0.068	-6	sf
8.9	7700	154	-0.021	-14	ss,sf
10.4	6600	133	-0.034	-26	sf

5e)Streaming Current of Aerosol 22 @ 0.067 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0					ns,hf
4.5	30600	612	0.075	7	ns,hf
5.9	51000	1020	-0.160	-7	hf
7.0	114500	2290	0.108	22	ss,hf
9.0	24000	481	0.110	76	ss,sf
10.5	7200	144			ss,hf

5f)Streaming Current of Aerosol 22 @ 0.133 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0					ns,hf
4.5	30500	609	-0.066	-11	ns,hf
5.8	42600	854	-0.120	-14	ns,sf
7.3	59900	1198	-0.140	-12	sf
9.0	29000	580	-0.110	-19	ss,sf
10.5	8250	165	-0.045	-27	sf

6a)Streaming Current of Dodecylamine Hydrochloride 0.001 g/L + Dowfroth (5×10^{-6} M)

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.1	7800	156	0.007	4	nf
4.3	32000	639	0.032	5	nf
5.8	1200000	11107	-0.040	0	check
5.8	1200000	11107	-0.040	0	nf
7.3	102000	2040	0.037	2	nf
9.0	43000	859	0.090	10	nf
10.4	8000	160	0.233	146	nf
10.5	7000	140	0.072	51	check

6b)Streaming Current of Dodecylamine Hydrochloride 0.009 g/L + Dowfroth (4×10^{-5} M)

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
? charge 3.1	8000	161	0.054	34	nf
3.0	3720	75	-0.026	-35	repeat,sf
4.3	181000	3621	0.005	0	nf
4.5	72100	1442	0.006	0	repeat,sf
5.7	319000	6384	0.035	1	check
5.8	355000	7105	-0.068	-1	nf
7.4	340000	6803	-0.061	-1	nf
7.4	251000	5023	0.016	0	repeat,sf
8.2	140000	2799	0.002	0	repeat
8.7	122000	2440	-0.250	-10	repeat
8.8	140000	2799	-0.100	-4	nf
9.0	129000	2580	-0.600	-23	repeat
? charge 10.3	8650	170	0.120	71	nf
? charge 10.4	9200	184	0.115	63	check
10.5	17800	356	-0.330	-93	repeat

6c)Streaming Current of Dodecylamine Hydrochloride 0.018 g/L + Dowfroth (8×10^{-5} M)

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	3100	64	-0.003	-5	sf
4.5	90200	1804	0.018	1	sf
5.9	194000	3882	0.014	0	sf
7.4	71500	1431	-0.022	-2	sf
9.0	49200	985	-0.330	-34	ss,nf,scum
10.4	7200	145	-0.210	-145	ss,nf,scum

6d) Streaming Current of Dodecylamine Hydrochloride 0.018 g/L + Dowfroth (8×10^{-5} M)

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.1	4350	88	-0.014	-16	
4.5	60500	1211	0.056	5	
5.9	189000	3782	0.008	0	
7.2	82900	1659	0.011	1	
7.3	127000	2540	-0.008	0	repeat,nf
7.9	124500	2490	-0.007	0	nf
8.5	114500	2280	-0.200	-9	repeat,nf
9.0	95000	1899	-0.730	-38	repeat,nf
9.1	76200	1525	-0.570	-37	
10.5	7450	150	-0.150	-100	

7a)Streaming Current of Styrene Phosphonic Acid @ 0.067 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.2	10000	201	-0.008	-4	ss,sf
4.4	31500	629	-0.024	-4	ss,sf
6.0	25500	510	-0.035	-7	ss,sf
7.4	16800	336	-0.035	-10	ss,sf
9.0	11100	223	-0.033	-15	ss,sf
10.4	7800	156	-0.025	-16	ss,sf

7b)Streaming Current of Styrene Phosphonic Acid @ 0.133 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.1	6050	121	-0.002	-2	ss,sf
4.5	18200	364	-0.035	-10	ss,sf
6.1	18000	360	-0.029	-8	ss,sf
7.5	12800	257	-0.036	-14	ss,sf
9.0	9500	190	-0.038	-20	ss,sf
10.5	7310	146	-0.030	-20	ss,sf

7c)Streaming Current of Styrene Phosphonic Acid @ 0.200 g/L + Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.1	4750	95	-0.011	-12	ss,sf
4.4	17000	340	-0.022	-6	ss,sf
6.0	16400	328	-0.024	-7	ss,sf
7.5	9350	188	-0.022	-12	ss,sf
9.0	7640	153	-0.024	-16	ss,sf
10.5	6000	121	-0.019	-16	ss,sf

8a)Streaming Current of Procol 540 @ 0.050 g/L - No Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	4800	96	-0.038	-40	sf
4.4	21600	431	-0.041	-10	sf
6.0	147000	2939	-0.190	-6	nf,ns
7.3	151000	3022	-0.190	-6	nf
8.9	71000	1421	-0.250	-18	nf
10.4	5790	116	-0.066	-57	hf

8b)Streaming Current of Procol 540 @ 0.075 g/L - No Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	3800	76	-0.006	-8	sf
4.6	52500	1050	-0.090	-9	sf
6.0	60000	1199	-0.160	-13	sf
7.5	62000	1240	-0.250	-20	nf
8.6	92000	1839	-0.170	-9	check
8.8	92000	1839	-0.180	-10	sf
10.5	6700	135	-0.060	-44	hf

8c)Streaming Current of Procol 540 @ 0.100 g/L - No Dowfroth

pH	R_{cell} (ohms)	R_{series} (ohms)	V (mv)	I X 10^8 (amps)	Comments
3.0	5320	106	-0.023	-22	hf
4.4	37400	747	-0.021	-3	hf
6.0	42800	855	-0.100	-12	f
7.4	46000	919	-0.160	-17	nf
9.0	61000	1223	-0.280	-23	hf
10.5					hf,ns

QUARTZ ZETA POTENTIAL RESULTS

On the following pages the raw zeta potential data for quartz is presented in tabular form. This data is shown graphically in Figures B1-B8.

1a)Zeta Potential of Sodium Oleate @ 0.007 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	53000	-0.6	-21
4.4	307000	-6.8	-44
6.4	1100000	-160.0	-290
7.3	1560000	-87.2	-111
8.9	1220000	-54.7	-89
10.5	164000	-7.3	-89

C = 20.54

1b)Zeta Potential of Sodium Oleate @ 0.013 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	33000	-0.3	-19
4.4	579000	-19.8	-68
6.0	1420000	-107.8	-151
7.8	2240000	-137.7	-122
8.7	129200	-65.5	-1009
8.7	27000	-10.2	-752
10.5	84000	-4.1	-96

1c)Zeta Potential of Sodium Oleate @ 0.027 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	47900	-0.4	-18
3.8	270000	-7.8	-58
6.6	386000	-19.8	-102
8.5	1420000	-83.6	-117
9.4	950000	-47.5	-100
10.4	245000	-10.1	-82

2a) Zeta Potential of Sodium Lauryl Sulphate @ 0.004 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	32600	-0.4	-22
4.5	680000	-23.5	-69
5.5	2150000	-145.5	-135
7.3	309000	-14.1	-91
9.1	250000	-10.4	-83
10.5	99000	-4.8	-96

C = 20.54

2b) Zeta Potential of Sodium Lauryl Sulphate @ 0.008 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
2.9	98000	-2.3	-46
4.4	400000	-24.1	-120
5.8	1580000	-157.0	-198
7.4	545000	-29.8	-109
9.1	302000	-16.6	-109
10.4	46200	-2.1	-89

2c) Zeta Potential of Sodium Lauryl Sulphate @ 0.016 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	154000	-3.3	-43
4.5	485000	-28.7	-118
5.8	173000	-43.2	-497
7.6	190000	-11.5	-120
9.1	146000	-9.3	-127
10.4	70000	-3.0	-85

3a) Zeta Potential of Briquest 281-25S @ 0.133 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	95500	-0.8	-18
4.6	213000	-9.3	-87
6.6	29300	-13.4	-910
6.6	25000	-11.7	-932
7.6	47400	14.9	626
7.6	24500	-8.1	-658
8.9	241000	-13.7	-113
10.5	111000	-4.8	-86

C = 20.54

3b) Zeta Potential of Briquest 281-25S @ 0.200 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	70000	-0.7	-19
4.5	226000	-5.4	-48
6.6	173000	-10.7	-123
7.4	237000	-9.3	-78
9.1	186000	-9.8	-105
10.4	108000	-4.6	-84

3c) Zeta Potential of Briquest 281-25S @ 0.267 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	54000	-0.5	-19
4.5	154000	-3.2	-41
6.9	142000	-7.4	-103
7.5	190000	-7.2	-76
9.1	146000	-7.5	-103
10.4	101000	-5.0	-99

4a) Zeta Potential of Salicylaldehyde @ 0.133 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
			-58
3.1	17300	-0.5	-389
4.5	18400	-3.6	-462
5.5	16800	-3.9	-1778
7.7	15000	-13.4	-664
9.1	21300	-7.1	-418
10.5	20000	-4.2	

C = 20.54

4b) Zeta Potential of Salicylaldehyde @ 0.200 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
			-82
3.0	21300	-0.9	-1164
4.5	26000	-15.2	-244
5.4	21000	-2.6	-2160
7.4	20000	-21.7	-541
9.1	19400	-5.3	-314
10.5	19000	-3.0	

4c) Zeta Potential of Salicylaldehyde @ 0.267 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
			-16
3.1	15700	-0.1	-186
4.3	22200	-2.1	-306
5.4	25200	-3.9	-1812
7.4	24500	-22.3	-364
9.1	22500	-4.1	-229
10.5	19100	-2.2	

5a) Zeta Potential of Aerosol 22 @ 0.017 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	118000	-1.4	-24
4.4	592000	-24.3	-82
6.0	171000	-162.9	-1896
7.6	217000	-9.4	-86
8.9	187000	-9.5	-101
10.4	78500	-3.6	-92

C = 20.54

5b) Zeta Potential of Aerosol 22 @ 0.033 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	78000	-1.3	-34
4.5	606000	-22.1	-73
6.2	265000	-85.9	-645
7.7	612000	-30.4	-99
9.1	435000	-22.9	-105
10.5	80000	-3.9	-97

5c) Zeta Potential of Aerosol 22 @ 0.067 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	56200	-0.5	-17
4.5	395000	-15.3	-77
6.7	810000	-45.3	-111
7.5	667000	-29.3	-87
8.9	405000	-21.1	-104
10.4	219000	-8.5	-77

6a) Zeta Potential of Dodecylamine Hydrochloride 0.001 g/L + Dowfroth (5×10^{-6} M)

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	46200	-0.2	-6
4.5	1460000	-22.5	-31
5.7	585000	-10.2	-35
7.3	831000	-32.6	-78
9.0	650000	-25.4	-78
10.5	165000	-5.8	-69

C = 20.54

6b) Zeta Potential of Dodecylamine Hydrochloride @ 0.009 g/L + Dowfroth (4×10^{-5} M)

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	55000	-0.3	-11
4.4	1360000	-18.6	-27
5.7	1710000	-82.3	-96
7.6	600000	-20.6	-68
8.9	365000	-7.3	-40
10.4	81000	-0.6	-14

6c) Zeta Potential of Dodecylamine Hydrochloride @ 0.018 g/L + Dowfroth (8×10^{-5} M)

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	59000	-0.2	-5
4.5	662000	-8.4	-25
6.0	2125000	-54.2	-51
7.8	1040000	-21.1	-40
9.0	760000	2.6	7
9.9	440000	3.0	14
10.4	239000	2.3	19

7a) Zeta Potential of Styrene Phosphonic Acid @ 0.067 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.3	15500	-4.9	-623
3.3	8000	-2.3	-572
4.3	44000	-8.8	-399
4.3	23500	-5.3	-449
6.0	112000	-5.6	-99
7.6	139000	-7.1	-101
8.9	120500	-5.7	-94
10.5	57000	-2.4	-83

C = 20.54

7b) Zeta Potential of Styrene Phosphonic Acid @ 0.133 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.4	132000	-1.7	-25
4.4	188000	-7.9	-84
6.1	230000	-8.4	-72
7.4	154000	-5.7	-74
9.0	104000	-4.5	-86
10.4	75100	-3.5	-94

7c) Zeta Potential of Styrene Phosphonic Acid @ 0.200 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	47200	-0.9	-36
4.5	156000	-4.9	-62
6.0	183700	-5.9	-64
7.0	122000	-4.1	-66
9.1	74000	-3.4	-92
10.5	74000	-3.0	-81

8a) Zeta Potential of Procol 540 @ 0.050 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	91000	-1.4	-31
4.5	406000	-19.3	-95
5.9	265000	-34.3	-258
7.2	2470000	-75.2	-61
9.1	250000	-10.4	-83
10.4	98500	-5.9	-119

C = 20.54

8b) Zeta Potential of Procol 540 @ 0.075 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	82000	-1.3	-32
4.5	215000	-8.1	-75
6.0	233000	-14.6	-125
7.5	179000	-8.2	-92
8.6	950000	-62.3	-131
10.4	181000	-8.1	-89

8c) Zeta Potential of Procol 540 @ 0.100 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	98000	-3.7	-75
4.4	298000	-13.3	-89
6.0	350000	-32.0	-182
7.5	320000	-11.8	-73
8.6	503000	-46.4	-184
10.4	95000	-6.0	-126

CASSITERITE ZETA POTENTIAL RESULTS

On the following pages the raw zeta potential data for cassiterite is presented in tabular form. This data is shown graphically in Figures B9-B16.

1a) Zeta Potential of Sodium Oleate @ 0.007 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	4950	-0.1	-3
4.5	15300	-1.7	-24
6.6	64000	-80.9	-276
7.4	13600	-1.8	-29
8.8	46500	-7.1	-33
10.4	35000	-2.0	-12

C = 2.25

1b) Zeta Potential of Sodium Oleate @ 0.013 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.2	8500	-0.3	-7
4.6	43200	-8.7	-44
5.9	57000	-65.2	-249
7.5	53500	-74.8	-305
9.1	7820	-2.1	-59
10.5	5440	-1.1	-46

1c) Zeta Potential of Sodium Oleate @ 0.027 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	4200	0.1	3 poor
4.4	14400	-2.1	-32
6.2	16100	-3.6	-49
7.3	16200	-5.7	-77
8.5	34200	-29.4	-187
10.4	9500	-2.8	-65

2a) Zeta Potential of Sodium Lauryl Sulphate @ 0.004 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.2	5500	-0.2	-9
4.4	6300	-0.9	-33
5.6	61000	-74.3	-266
7.3	34000	-13.9	-89
9.2	28000	-12.4	-97
10.6	12200	-3.9	-70

C = 2.25

2b) Zeta Potential of Sodium Lauryl Sulphate @ 0.008 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.2	8100	-1.0	-27
4.4	31500	-12.1	-84
5.9	82000	-77.8	-207
7.3	42000	-26.9	-140
8.9	25500	-11.3	-97
10.4	10800	-2.0	-40

2c) Zeta Potential of Sodium Lauryl Sulphate @ 0.016 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	5920	-0.7	-26
4.4	63100	-16.0	-55
5.6	31000	-54.6	-384
7.6	43000	-27.0	-137
9.0	41100	-19.5	-103
10.5	20000	-2.7	-29

3a) Zeta Potential of Briquest 281-25S @ 0.133 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	4300	-0.1	-8
3.8	10620	-1.7	-34
6.7	15800	-8.6	-118
7.6	25000	-6.9	-60
9.1	13200	-3.4	-56
10.4	7620	-1.6	-47

C = 2.25

3b) Zeta Potential of Briquest 281-25S @ 0.200 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	5500	-0.2	-10
4.4	18350	-4.1	-49
5.9	23700	-6.2	-57
7.5	20200	-5.5	-59
9.1	14500	-4.0	-60
10.5	8150	-1.8	-49

3c) Zeta Potential of Briquest 281-25S @ 0.267 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	4050	0.0	1
4.4	13200	-2.6	-43
5.8	16600	-4.2	-55
7.6	14200	-3.9	-60
9.1	11000	-2.5	-50
10.5	6820	-1.4	-43

4a)Zeta Potential of Salicylaldehyde @ 0.133 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	3850	0.3	10
4.6	56000	-10.6	-28
5.6	58000	-22.6	-58
7.3	16200	-3.2	-30
8.9	13300	-2.9	-33
10.4	7820	-1.7	-32

C = 1.54

4b)Zeta Potential of Salicylaldehyde @ 0.200 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	3360	0.2	11
4.4	20500	-2.3	-17
5.7	101000	-92.2	-136
7.5	41800	-10.9	-39
9.0	11400	-1.8	-23
10.5	5290	-0.5	-15

4c)Zeta Potential of Salicylaldehyde @ 0.267 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	1620	0.2	18
4.5	31500	-5.3	-25
5.0	57000	-81.6	-214
6.2	41600	-17.2	-62
7.5	57100	-7.9	-21
9.0	9500	-1.6	-25
10.5	5400	-1.2	-32

5a)Zeta Potential of Aerosol 22 @ 0.017 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	5000	-0.6	-26
4.4	34000	-12.3	-79
5.9	13900	-79.2	-1242
7.6	40000	-19.8	-108
9.0	31000	-10.6	-75
10.4	11100	-2.2	-42

C = 2.25

5b)Zeta Potential of Aerosol 22 @ 0.033 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	7000	-0.7	-22
4.6	39000	-16.9	-94
6.6	22800	-49.1	-469
7.4	50900	-15.8	-68
9.1	24000	-9.8	-89
10.4	14000	-2.4	-38

5c)Zeta Potential of Aerosol 22 @ 0.067 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	3210	-0.5	-34
4.4	18400	-7.3	-86
6.4	29500	-37.5	-277
7.3	6000	-2.8	-71
7.5	49000	-22.0	-98
9.0	9300	-2.2	-35
9.0	25000	-8.2	-71
10.4	7250	-1.6	-47

6a) Zeta Potential of Dodecylamine Hydrochloride @ 0.001 g/L + Dowfroth (5×10^{-6} M)

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	8000	0.3	7
4.4	36200	-9.5	-57
5.8	15400	-145.3	-2057
7.6	52500	-20.5	-85
8.8	22600	-10.9	-105
10.3	18800	-2.9	-34

C = 2.25

6b) Zeta Potential of Dodecylamine Hydrochloride @ 0.009 g/L + Dowfroth (4×10^{-5} M)

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	9800	0.7	14
4.5	66000	-1.6	-5
5.1	42000	-28.7	-149
6.1	69000	-10.4	-33
7.3	51000	-7.8	-33
9.1	32400	-5.0	-33
10.4	16300	-1.4	-18

6c) Zeta Potential of Dodecylamine Hydrochloride @ 0.018 g/L + Dowfroth (8×10^{-5} M)

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	11800	0.4	8
4.9	37300	3.3	19
5.9	65000	-1.0	-3
7.6	70000	-0.8	-3
9.1	37900	-2.4	-14
10.5	13900	-0.3	-5

7a) Zeta Potential of Styrene Phosphonic Acid @ 0.067 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.3	16780	-1.8	-23
4.5	34000	-10.3	-66
6.3	38600	-12.6	-71
7.5	25400	-7.8	-67
9.0	14950	-4.4	-65
10.4	9000	-2.1	-51

C = 2.25

7b) Zeta Potential of Styrene Phosphonic Acid @ 0.133 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.2	7220	-0.8	-24
4.4	13400	-5.0	-81
6.1	38600	-5.7	-32
7.4	18400	-3.7	-44
9.1	12900	-2.3	-39
10.4	5500	-1.8	-71

7c) Zeta Potential of Styrene Phosphonic Acid @ 0.200 g/L + Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	5130	-0.7	-31
4.6	8000	-3.2	-86
6.0	14600	-3.8	-56
7.4	9300	-2.1	-49
8.9	7710	-1.6	-44
10.4	5990	-0.9	-33

8a) Zeta Potential of Procol 540 @ 0.050 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	6700	-0.8	-27
4.3	28600	-8.2	-63
6.0	17400	-13.5	-169
7.2	31600	-32.1	-221
9.1	24100	-10.0	-90
10.4	6600	-1.2	-39

C = 2.25

8b) Zeta Potential of Procol 540 @ 0.075 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.1	1920	-0.3	-32
4.3	14600	-4.0	-60
6.1	27500	-11.4	-90
7.8	43200	-18.8	-95
8.9	27100	-8.6	-69
10.5	12000	-3.2	-58

8c) Zeta Potential of Procol 540 @ 0.100 g/L - No Dowfroth

pH	Rcell (ohms)	E/P	Zeta Pot. (mv)
3.0	4640	-0.8	-35
4.4	19600	-7.1	-79
6.1	22900	-8.8	-84
7.3	26400	-15.7	-130
9.0	18400	-5.5	-65
10.4	6200	-1.5	-53

MICROFLOTATION RESULTS

On the following pages the raw flotation results as well as the appropriate pH, streaming current, and zeta potential are presented in tabular form. The result 18/5 indicates that the first flotation test gave a recovery of 18% by weight while a repeat gave a 5% recovery. This data is presented graphically in Figures 4-19.

pH	Stream Current (amps x 10^8)	Flotation Results: Quartz Zeta Pot (mv)	Quartz -45 +38 (%)	Quartz -10 +5 (%)	Quartz -5 (%)	Cassiterite Zeta Pot (mv)	Cassiterite -45 +38 (%)	Cassiterite -10 +5 (%)	Cassiterite -5 (%)
1) Sodium Oleate @ 0.013 g/L (~20 g/Mt + Dowfroth 250 @ 20 g/Mt)									
3.0	-24	-19	20	18/5	3	-7	62	4	-
4.5	-5	-68	24	3	3	-44	65/45	4	-
6.0	-20	-151	10	2	3	-249	65	5	-
7.5	-7	-122	19/37/34	4	3	-305	84	6	-
9.0	-14	-1009	11	2	2	-59	82/57/65/60	5	-
10.5	-35	-96	10	2	2	-46	84/39/56	3	-
2) Sodium Lauryl Sulphate @ 0.004 g/L (~6 g/Mt + Dowfroth 250 @ 20 g/Mt)									
3.0	-47	-22	15	4	-	-9	78	2	-
4.5	0	-69	11	2	-	-33	81/22/25	3	-
6.0	-1	-135	11	3	-	-266	79	3/3	-
7.5	-4	-91	10	2	-	-89	70	2	-
9.0	-12	-83	10	2	-	-97	68	2	-
10.5	-64	-96	8	3	-	-70	31/18	2	-
Sodium Lauryl Sulphate @ 0.016 g/L (~24 g/Mt + Dowfroth 250 @ 20 g/Mt)									
3.0	-20	-43	9						
4.5	0	-118	11						
6.0	-1	-497	13						
7.5	-1	-120	12						
9.0	-5	-127	11						
10.5	-82	-85	3						
3) Briquest 281-25S @ 0.133 g/L (~200 g/Mt + Dowfroth 250 @ 20 g/Mt)									
3.0	-23	-18	38/7	14	-	-8	75	4	2
4.5	-4	-87	41	8	-	-34	71/63	2	2
6.0	-2	-910	16	5	-	-118	61	3	2/2
7.5	-5	-626	8	5	-	-60	58	3	2
9.0	-8	-113	8	5	-	-56	9/18	3	2
10.5	-48	-86	8	4	-	-47	4	2	3

pH	Stream Current (amps x 10^8)	Flotation Results: Quartz Zeta Pot (mv)	Quartz -45 +38 (%)	Quartz -10 +5 (%)	Quartz -5 (%)	Cassiterite Zeta Pot (mv)	Cassiterite -45 +38 (%)	Cassiterite -10 +5 (%)	Cassiterite -5 (%)
4) Salicylaldehyde @ 0.0133 g/L (~200 g/Mt + Dowfroth 250 @ 20 g/Mt)									
3.0	-60	-58	47	12	-	10	11	4	-
4.5	-2	-389	44	13	-	-28	8/43/44	3	-
6.0	0	-462	45	14	-	-58	21/33	2	-
7.5	-13	-1778	17	3	-	-30	27	2	-
9.0	-9	-664	18	6	-	-33	7	2	-
10.5	-28	-418	20	3	-	-32	6/20	4	-
5) Aerosol 22 @ 0.067 g/L (~100 g/Mt - no frother)									
3.0	n/a	-17	40	2	-	-34	82	5	-
4.5	n/a	-77	30/36	2	-	-86	70	16/4	7
6.0	0	-111	52	3	-	-277	73	11	7
7.5	-10	-87	52	3	-	-98	80	6	-
9.0	-13	-104	36	4	-	-711	78	2	-
10.5	-31	-77	16	3	-	-47	93/92	2	-
6) Dodecylamine Hydrochloride @ 0.001 g/L (~2 g/Mt + Dowfroth 250 @ 20 g/Mt)									
3.0	4	-6	36/48	8/12	25/9/7	7	5	2	2
4.5	5	-31	67	22	25/10	-57	5	3	3
6.0	0	-35	88/75	21	10	-2057	20/18	2	2
7.5	2	-78	82	24	12	-85	17	2/9	2
9.0	10	-78	84	27	10	-105	66/59	3	3
10.5	51	-69	86	21	10	-34	64	3	3
7) Styrene Phosphonic Acid @ 0.067 g/L (~100 g/Mt + Dowfroth 250 @ 20 g/Mt)									
3.0	-4	-623	4	4	-	-23	61	6	4
4.5	-4	-399	5	4	-	-66	54	4	7
6.0	-7	-99	4	4	-	-71	54	4	2
7.5	-10	-101	4	4	-	-67	19	3	2
9.0	-15	-94	20/13	3	-	-65	11/13	2	2
10.5	-16	-83	21	3	-	-51	10	3	3

		Flotation Results							
		Quartz				Cassiterite			
pH	Stream Current (amps x 10^8)	Zeta Pot (mv)	-45 +38 (%)	-10 +5 (%)	-5 (%)	Zeta Pot (mv)	-45 +38 (%)	-10 +5 (%)	-5 (%)
8) Procol 540 @ 0.050 g/L (~75 g/Mt - no frother)									
3.0	-40	-31	5	4	-	-27	73	5	-
4.5	-10	-95	3	5	-	-63	65	9	-
6.0	-6	-258	1	1	-	-169	53	4	-
7.5	-6	-61	1	2	-	-221	61	3	-
9.0	-18	-83	1	2	-	-90	8/34	3	-
10.5	-57	-119	1	3	-	-39	4	3	-

APPENDIX E

REAGENT SOURCES

APPENDIX E - REAGENT SOURCES

COLLECTORS

1) Sodium Oleate	- Fisher Scientific
2) Sodium Lauryl Sulphate	- Fisher Scientific
3) Briquest 281-25S	- Albright and Wilson Ltd.
4) Salicylaldehyde	- Fisher Scientific
5) Aerosol 22	- Cyanamid of Canada Ltd.
6) Dodecylamine Hydrochloride	- Eastman Kodak
7) Styrene Phosphonic Acid	- Cominco
8) Procol 540	- Allied Colloids

Frother

1) Dowfroth 250	- Dow Chemical

pH Control

1) HCl	- Amachem
2) NaOH	- BDH Chemicals

Zeta Cell Calibration

1) KCl	- Anachemia